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CANADIAN JOURNAL OF AGRICULTURAL SCIENCE

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VOLUME 33 MARCH-APRIL, 1953 No. 2

CONSUMPTIVE USE OF WATER IN ORCHARD SOILS

I. EFFECTS OF SOIL DEPTH[1]

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ABSTRACT

Two investigations are reported, both dealing with the effects of depth in the soil on the rate of consumptive use of water from orchard soils.

In the first investigation, 41 determinations of consumptive use were made in mature apple orchards. The procedure used was to take soil samples to a depth of six feet following an irrigation and again prior to the next irrigation, determine their moisture contents, and from the data obtained determine the rate of consumptive use per day for each foot of depth. It was found that the rate of consumptive use was greatest in the top foot, and decreased progressively with an increase in depth. In older orchards there was still some consumptive use at a depth of six feet. In most cases, the rate of consumptive use was negligible below a depth of four feet.

In the second investigation, two plots of apple trees were selected for study that were not irrigated. Changes in moisture content throughout the season were determined by periodic sampling of the soil and by the use of Bouyoucos gypsum resistance blocks. Early in the season, the rate of consumptive use was greatest near the surface and decreased with greater depth. As the top foot of soil dried out, however, the rate of water use increased in the second and third feet, and later still in the fourth and fifth feet. By the end of the season almost all of the soil to the fourth foot had dried down to the wilting point; thus, the total consumptive use for the season showed only a comparatively small decrease with an increase in depth to four feet.

INTRODUCTION

"Consumptive use" of water may be defined as the use of water from the soil by plants, together with the loss of water by evaporation from the surface of the soil (7). Thus, in an orchard, consumptive use includes water absorption by the roots of trees and cover crop, plus water loss by evaporation directly from the soil. It does not include the water lost from the root area by percolation following an irrigation. The rate of consumptive use is usually expressed in terms of inches of water per day.

The advent of sprinkler irrigation in British Columbia has emphasized the need for a fuller understanding of what happens to the moisture in the soil during and between irrigations. In response to this need, an investigation has been conducted to determine the rate of consumptive use of water in soils of mature orchards in the Okanagan Valley in British Columbia, and to study the effects of certain factors on this rate of consumptive use. The results reported in this paper deal primarily with the effects of the depth of the soil on the rate of consumptive use. The effects of other factors will be reported in subsequent papers.

[1] Contribution No. 789 from the Division of Horticulture, Experimental Farms Service, Canada Department of Agriculture, Ottawa. The major part of this paper was presented at meetings of the Northwest Section of the American Society of Agricultural Engineers, held at Moscow, Idaho, October 25–27, 1951.

[2] Senior Horticulturist and Horticulturist, respectively, in charge of plant nutrition, soils and irrigation investigations.

REVIEW OF LITERATURE

A number of investigators have reported that they have found the rate of consumptive use of water in deciduous orchards to be normally greatest near the surface, and to lessen progressively with increase in depth. Veihmeyer (14) found decreasing moisture use with greater depth in irrigated prune orchards in California. Some moisture was used, however, to a depth of 12 feet. Aldrich, Work and Lewis (1), in tests with pear trees in Oregon, reported that the percentages of water lost from the top four feet of soil were 34, 28, 22 and 16 per cent, from the top foot to the fourth foot respectively. In addition, smaller amounts were used from below this depth. In contrast with such results are those obtained in non-irrigated areas. For example, Schuster and Stephenson (13), working with nut trees in Oregon, found that in some cases the amount of water used at depths of 5 and 6 feet was almost as great as that used in the top two feet. Yokum (17) in Nebraska has reported heavy water use from the soil to a depth of 10 feet and more, by young apple trees.

Among the factors that have been found responsible for reduced moisture absorption at lower depths are the lesser concentrations of fibrous roots at those depths, colder temperatures, and lack of aeration. Workers have commonly found (1, 6, 11, 12, 13, 15) a reduction in concentration of absorbing roots at greater depths. Pillsbury, Compton and Picker (12) reported that 37 per cent of the total consumptive use of water to a depth of six feet, in a mature citrus orchard, occurred in the top foot. The percentages for the second, third, fourth, fifth, and sixth feet were 30, 15, 11, 4 and 3 respectively. Working with guayule and corn in California, Hunter and Kelley (6) found that there was less root concentration and less water absorption with greater depth to a depth of six feet. This was under conditions of constant temperature at all depths. Aldrich, Work and Lewis (1) reported high positive correlations between the rate of consumptive use and the count of fibrous roots of pear trees. Conrad and Veihmeyer (4) reported similar findings with sorghum. It has also been found that the soil is normally colder at greater depths during the summer (8), and that its atmosphere contains a higher ratio of carbon dioxide to oxygen at greater depths (2, 5). In addition, it has been found that both colder temperatures (9) and an unfavourable ratio of carbon dioxide to oxygen (3) reduce the rate of water absorption by plant roots. It appears reasonable to assume from these findings, therefore, that all three of these factors are instrumental in lessening the rate of consumptive use of water at greater depths in the soil.

PROCEDURES

Extensive field investigations were conducted in both 1949 and 1950 to determine the consumptive use of water in mature apple orchards. Since the procedure used in 1950 included some refinements over that used in 1949, the only procedures and the only results that need be outlined here are those for 1950.

Small plots of mature apple trees were laid out in May of 1950 in grower-owned orchards in each of five districts. An attempt was made to select orchards in both light soils and heavy soils in each district. No

orchard was used that showed the presence of either gravel or seepage water in the top six feet. All orchards used were irrigated with under-tree sprinklers. Each plot consisted of four uniformly large, healthy trees, adjacent to one another in a square pattern. Most of the trees used were spaced 30 × 30 feet on the square, but some were spaced 25 × 25 feet. Later in the season it was found necessary to eliminate a number of plots, for various reasons. Chief among these reasons were the appearance of seepage water in the root area during the season, and heavy local rains between irrigations. The number and location of those plots finally used are summarized in Table 1. The districts noted in this table are distributed in a north-and-south direction in the Okanagan Valley. Vernon is approximately 93 miles north of Osoyoos, which is adjacent to the United States border.

TABLE 1.—DISTRIBUTION OF PLOTS BY DISTRICTS

District	No. of orchards	No. of plots	No. of tests made
Osoyoos	5	10	16
Summerland	5	10	13
Glenmore	3	3	3
Winfield	3	6	6
Vernon	2	3	3
Total	18	32	41

The first set of soil samples was taken just prior to an irrigation, partly for the purpose of checking for the presence of seepage water. The second set of samples was taken about 24 hours after completion of the irrigation; and in addition, 48 hours and 72 hours after in the heavier soils. The third set of samples was taken just prior to the next irrigation. If heavy rains occurred between the second and third times of sampling, the test was discarded. It was not found possible to develop a satisfactory method for determining how to assess a heavy rain with regard to its effects on consumptive use and irrigation requirements. Where possible, sampling was continued for a second irrigation cycle.

Three sampling locations were chosen in each "plot" or tree square, each location being halfway between the trunk of a tree and the centre of the square. At each sampling period, separate samples were taken at depths of 0-6 inches, 6-12 inches, and by one-foot depths to a depth of 6 feet. This was done at each sampling location, and no samples were composited. After the first sampling at each location, subsequent samples were taken within one foot of the first auger hole.

The soil samples thus obtained were held in closed cans until they could be weighed. After weighing they were dried to constant weight at 105° F. and were weighed again. The moisture contents thus determined on the second set of samples (one day after irrigation with sandy soils, three days after irrigation with heavy soils) were used as a measure of the field capacity for moisture. The differences between these moisture contents

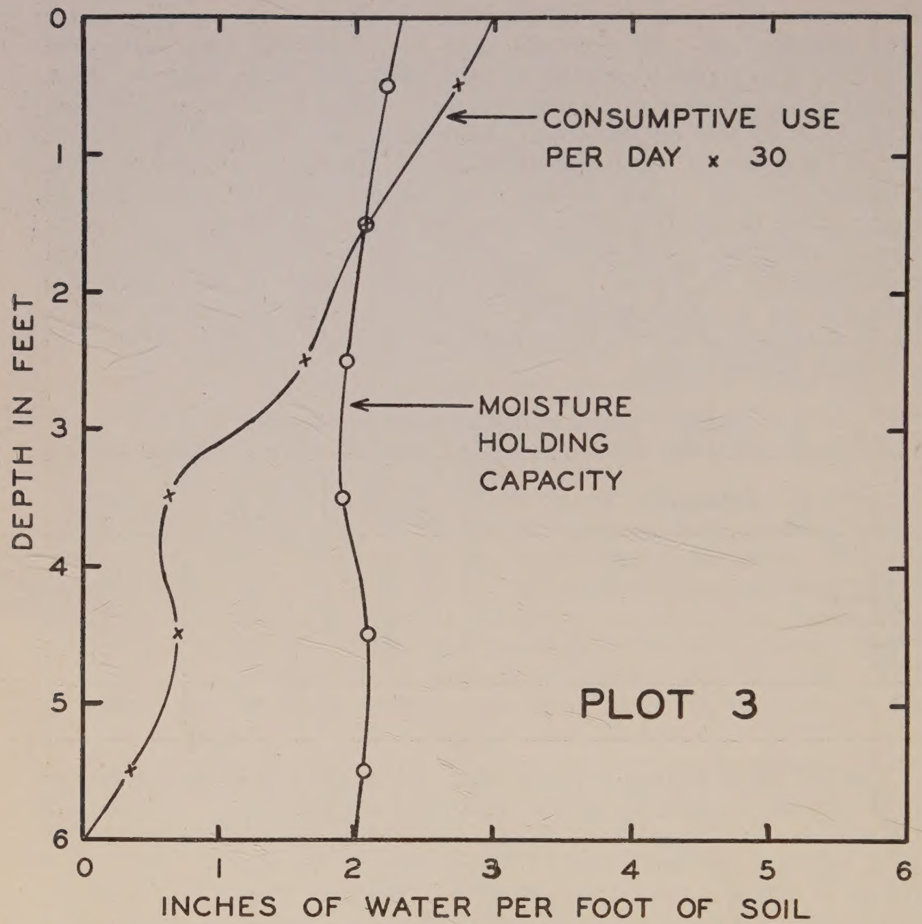

FIGURE 1. Effects of depth in the soil on the field capacity for moisture and on the rate of consumptive use of water in Plot 3. The field capacity is expressed in terms of inches of water per foot of soil. The soil in this plot is a loamy sand. The rate of consumptive use per day is expressed in inches of water, and is multiplied by 30. Each plotted point is located at the mid-point of the foot in depth of soil that it represents.

and those of the subsequent dry samples were divided by the number of days involved, to give the rate of consumptive use per day. For the sake of convenience, the number of days between the second and third samplings was called the "irrigation interval", though it was from one to four days shorter than the actual irrigation interval. Consumptive use figures for each plot were obtained by averaging the data from the three locations. In all cases the moisture content in per cent was used as a basis for determining the moisture content in inches per foot of soil, using the following equation developed previously by Wilcox (16):

$$FCF = 0.1904\ FC - 0.0003695\ FC^2 - 0.00002033\ FC^3$$

In this equation,

FCF = field capacity expressed as inches of water per foot of soil,
FC = field capacity expressed as per cent of the dry weight of the soil.

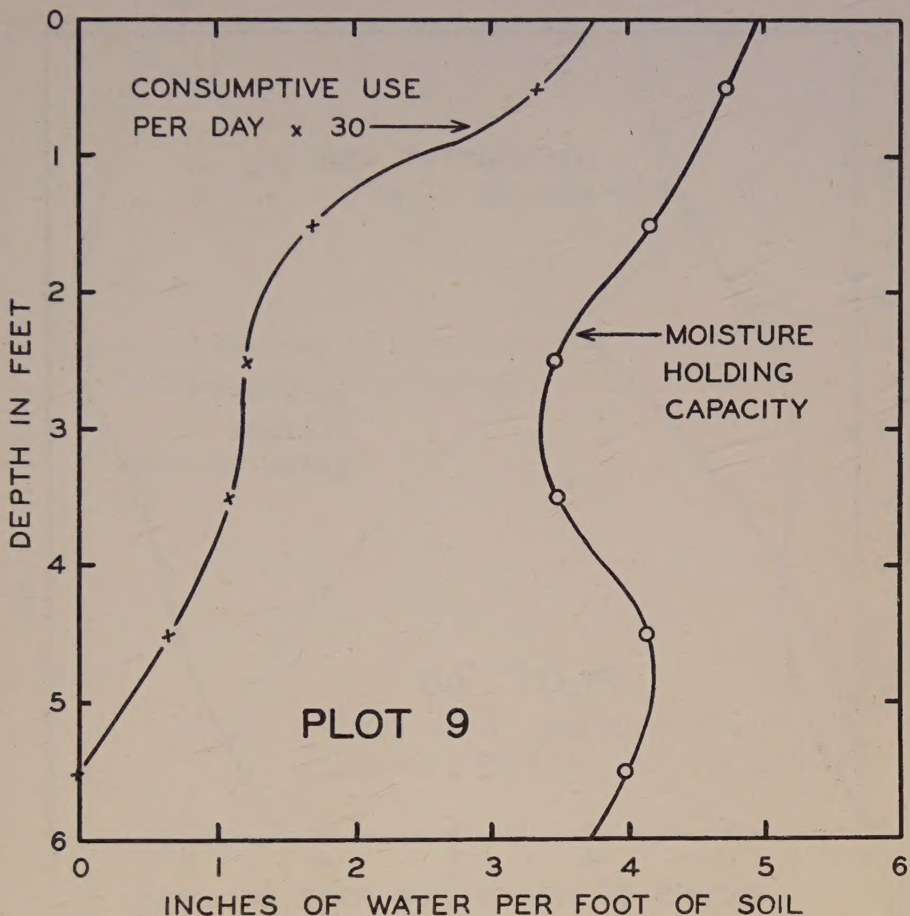

FIGURE 2. Effects of depth in the soil on the field capacity for moisture and on the rate of consumptive use of water in Plot 9. The field capacity is expressed in terms of inches of water per foot of soil. The soil in this plot is a silt loam. The rate of consumptive use per day is expressed in inches of water, and is multiplied by 30. Each plotted point is located at the mid-point of the foot in depth that it represents.

In addition to the above plot tests, samples of soil were taken once a week to a depth of seven feet in an additional plot in heavy soil (the Croil plot). The first samples were taken June 15, 1950, ten feet from the trunk of a mature McIntosh apple tree. Subsequent samples were spaced one foot apart in a circle around the tree. The last samples were obtained September 28, 1950. A similar procedure was used in a second plot in sandy loam soil (the Stevens plot). The moisture contents of the soil samples were determined. At the same time, electrical resistance readings were taken on Bouyoucos gypsum blocks placed at each foot to a depth of seven feet. These two plots are normally irrigated, but were not irrigated in 1950.

RESULTS

Consumptive Use under Normal Irrigation

In the 41 tests of rate of consumptive use, that were made in the intervals between irrigations in grower-owned orchards, the relative rates of

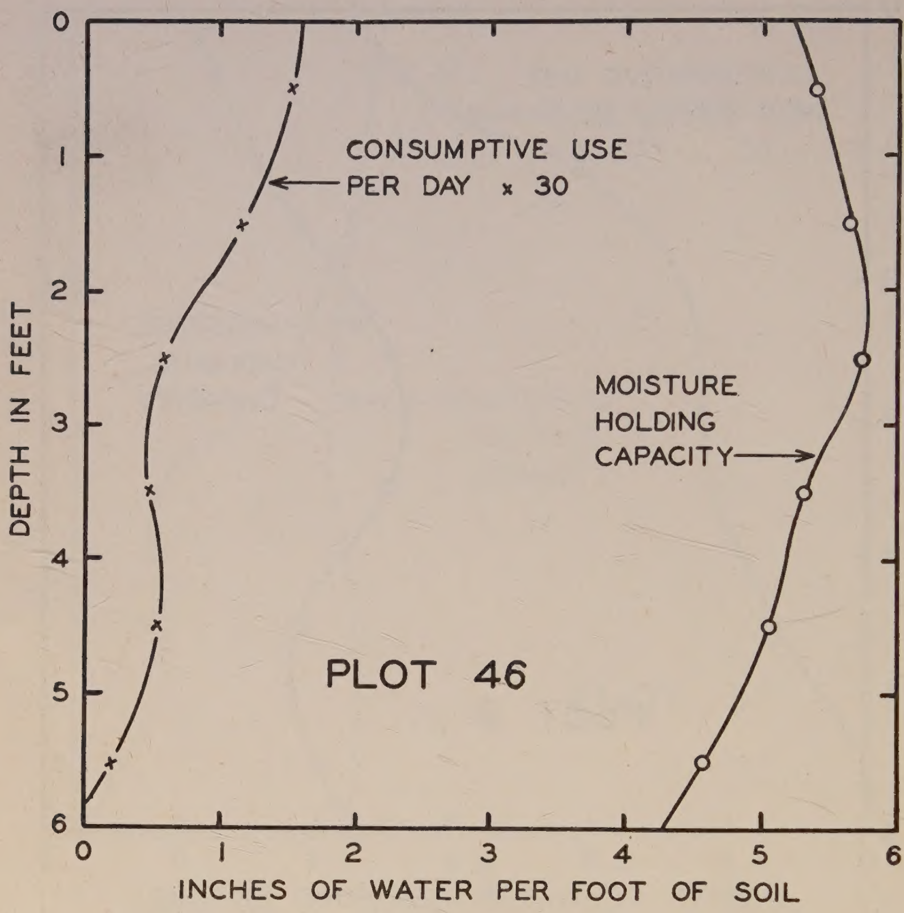

FIGURE 3. Effects of depth in the soil on the field capacity for moisture and on the rate of consumptive use of water in Plot 46. The field capacity is expressed in terms of inches of water per foot of soil. The soil in this plot is a clay loam. The rate of consumptive use per day is expressed in inches of water, and is multiplied by 30. Each plotted point is located at the mid-point of the foot in depth that it represents.

water use were compared at different depths in the soil. An inverse relationship was found between the depth of the soil and the rate of consumptive use; that is, the deeper the soil, to a depth of six feet, the less was the amount of water used out of each foot of soil. The degree of decrease in consumptive use with increase in depth varied widely from plot to plot. In some profiles, the rate of consumptive use did not decrease uniformly with greater depth. This usually appeared to be related to the texture of the soil, as measured by the field capacity for moisture. For example, a coarse sandy profile with a silty horizon in the middle of it would show higher consumptive use in this heavier horizon than either immediately above or below it. Indications from previous work by the author (15) were that in such a case the concentration of fibrous roots would be higher in the silty horizon.

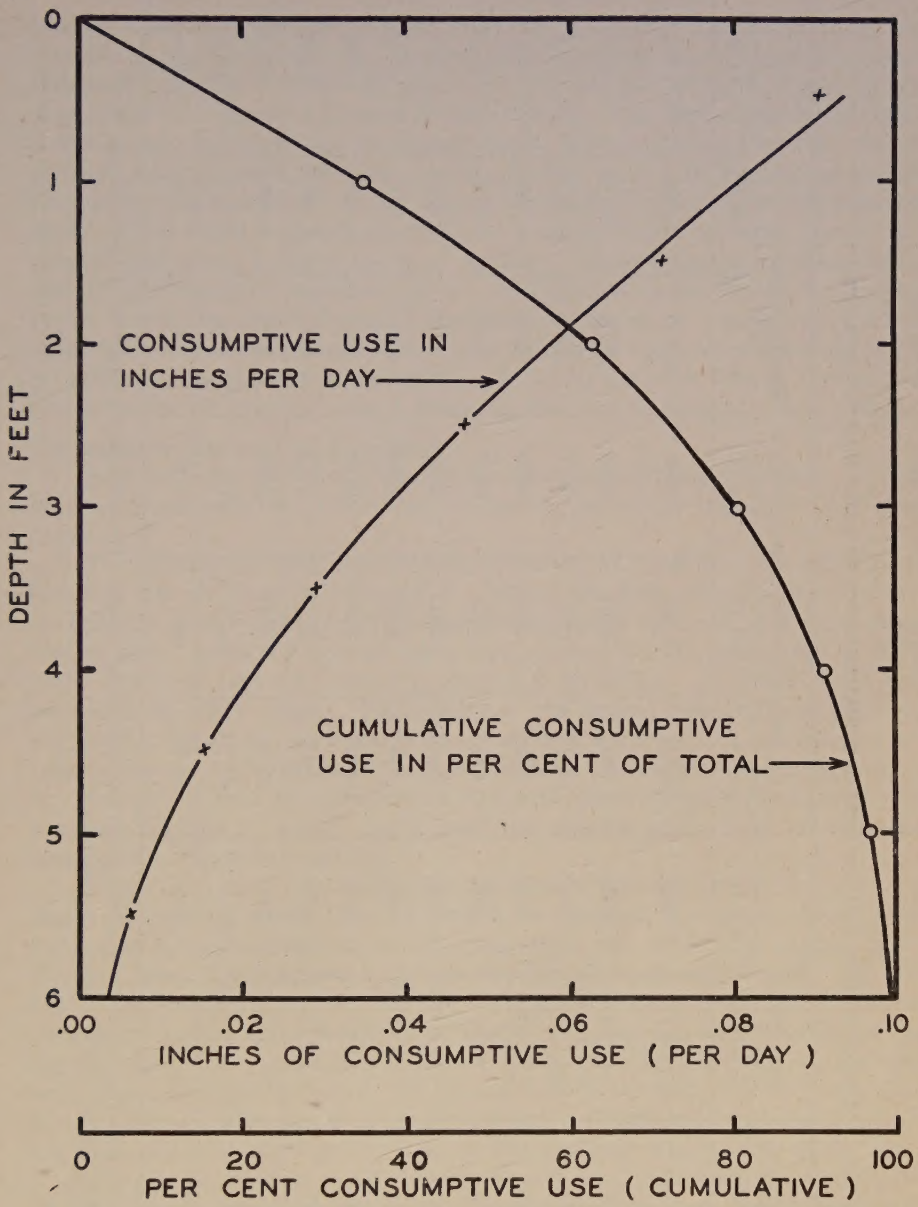

FIGURE 4. Effects of depth in the soil on the rate of consumptive use of water from the soil. In the one curve, the rate of consumptive use (in inches per day) is plotted at the central point of each foot of depth. In the other curve, these same values have been expressed in terms of percentage of the total consumptive use to six feet, and have been added cumulatively from the first foot to the sixth. The chart represents the averages of the eight plots in Table 2.

Some typical examples of the effects of depth on the rate of consumptive use are presented in Table 2. At the bottom is shown the average percentage of water removed from each foot of soil. These percentages are

TABLE 2.—EFFECTS OF SOIL DEPTH ON RATE OF CONSUMPTIVE USE OF WATER IN APPLE ORCHARDS*

Plot no.	Irrigation interval	Total field capacity to 6 feet	Daily rate of consumptive use at following depths:						
			0–1 ft.	1–2 ft.	2–3 ft.	3–4 ft.	4–5 ft.	5–6 ft.	Total
	days	inches	inches	inches	inches	inches	inches	inches	inches
3	13	12.24	.0906	.0687	.0537	.0205	.0232	.0145	.2712
7	12	15.01	.0962	.1010	.0817	.0664	.0338	−.0019	.3772
9	26	24.00	.1105	.0568	.0408	.0366	.0221	−.0007	.2661
18	26	21.91	.0927	.0716	.0626	.0227	.0023	.0146	.2665
20†	10	24.13†	.1604	.1220	.0623	.0320	.0130	.0013	.3910
24	11.5	6.82	.0662	.0406	.0236	.0198	.0098	.0111	.1711
44	10	14.61	.0625	.0725	.0351	.0171	.0021	.0033	.1926
46	37	31.75	.0504	.0382	.0198	.0163	.0182	.0066	.1495
Average			.0912	.0714	.0474	.0289	.0156	.0061	.2606
% of total			35.0	27.4	18.2	11.1	6.0	2.3	100.0
% of total, all plots			35.9	26.8	18.1	10.5	3.6	1.1	100.0

* Data from 8 plots are shown, to illustrate the normal variation in consumptive use with an increase in depth. The averages at the bottom are for these 8 samples. Average percentages are shown both for the 8 plots and for all plots.

† This was a heavy soil, irrigated by the grower much more frequently than necessary, hence showing a high rate of consumptive use.

quite similar to those reported by Pillsbury, Compton and Picker (12) for mature citrus orchards. It can be seen that the percentage of water removed from below four feet was relatively small. Plots 3, 9 and 46 are illustrated in Figures 1, 2 and 3 respectively. In these figures the consumptive use per day has, for convenience, been multiplied by 30. Comparison is shown with the field capacity in each case. In Figure 4 is shown the average consumptive use per day at each depth in the soil in the selected plots. This chart suggests that on the average there is some water use, though not much, below a depth of six feet. Data from many of the individual plots support this conclusion. In Figure 4 is also shown the cumulative water use from the soil, expressed in terms of percentage of total water used to a depth of six feet. The values for this curve were obtained by adding cumulatively the percentages shown for each foot in the second line from the bottom of Table 2, from the first foot to the sixth foot in order.

Consumptive Use without Irrigation

Results from the Croil plot and the Stevens plot were similar. It will be considered sufficient, therefore, to report the results from the Croil plot only.

The trends in moisture content obtained at each foot to a depth of five feet are indicated in Figure 5. When the first samples were taken, on June 15, some of the moisture had already been used out of the top three feet of soil. Several rains occurred from June 13 to 17, to a total of 0.79 inch, and from July 25 to 29 to a total of 2.62 inches. Light showers also occurred on other dates. The effects of the heavy rains late in July are reflected in the curve for moisture content in the top foot. Other irregularities in the curves were caused by soil variations from one sampling position to another. The sixth and seventh feet were quite irregular, as a result of a varying horizon of sandy loam, and the results with them cannot be considered altogether reliable.

It will be noted from Figure 5 that water was used from the soil to a depth of at least seven feet. Early in the season, the rates of use were similar to those reported above; that is, water was used most rapidly from the top foot and progressively less rapidly with greater depth. As the season progressed, however, and the surface soil became drier, this situation changed. Less water was removed from the upper soil and more from the deeper soil. On June 15, water was being rapidly used out of the top foot, and less rapidly out of the second and third feet. It was not until about June 29, that rapid use from the second and third feet commenced. By this time, the moisture content of the top foot was getting rather low. Rapid use in the fourth and fifth feet did not start until early in August, by which time the moisture in the top three feet was at a relatively low level.

This same situation is also illustrated in Figure 6, in which the moisture contents are charted by depths at four representative dates about one month apart. In this figure, the average moisture content for each foot of soil is entered at the mid-point of the foot, and free-hand curves have been drawn connecting these points. As with Figure 5, irregularities in the curves are largely due to soil variability. It will be noted that most of the loss of water from the top foot of soil occurred early in the season; and that the deeper the soil, the later in the season did the major loss of water occur.

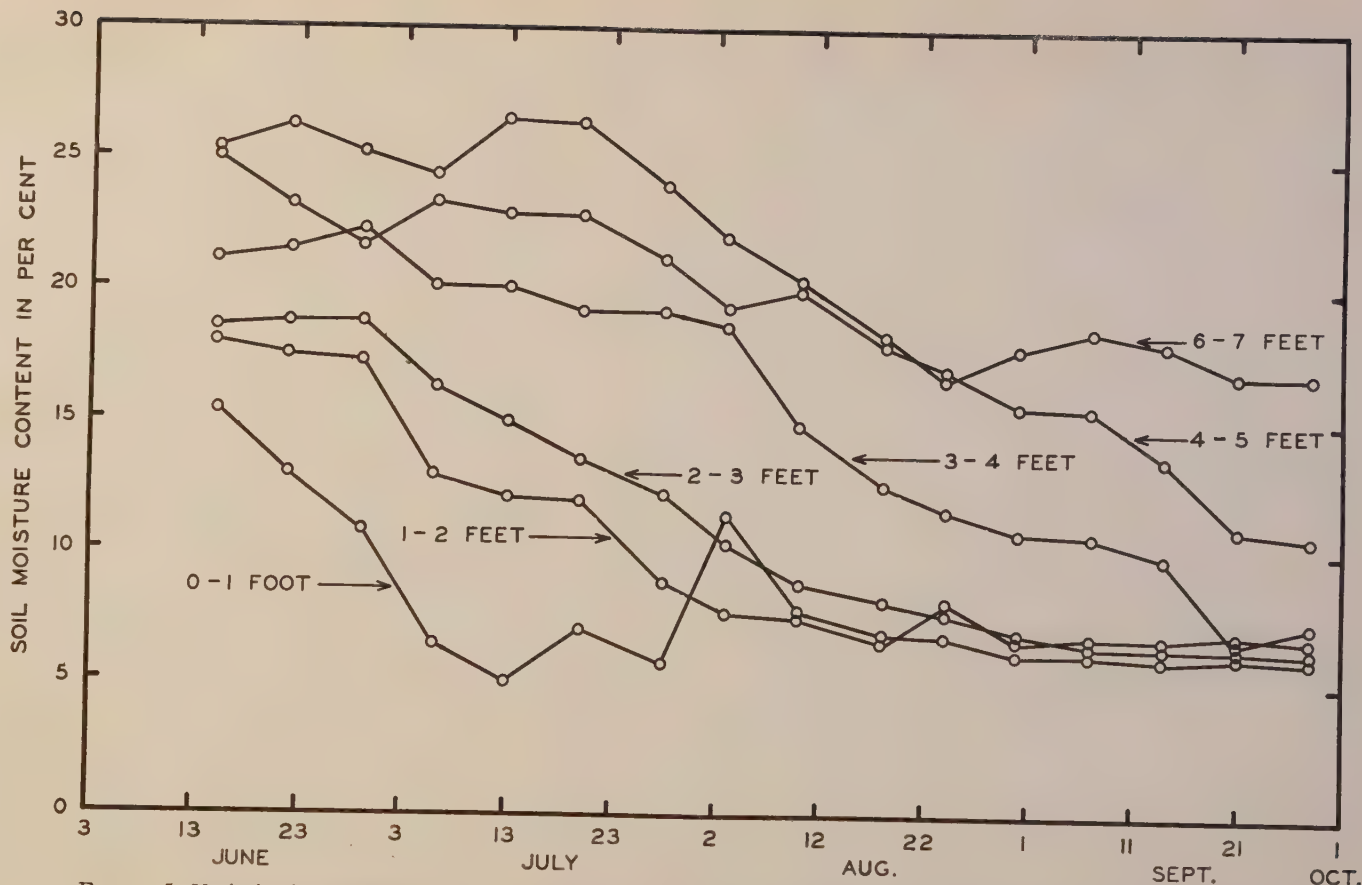

FIGURE 5. Variation in moisture content of the soil in the non-irrigated plot in the Croil orchard in 1950. The moisture contents are shown for each foot in depth to a depth of seven feet, with the exception of the sixth foot. Rains occurred late in July.

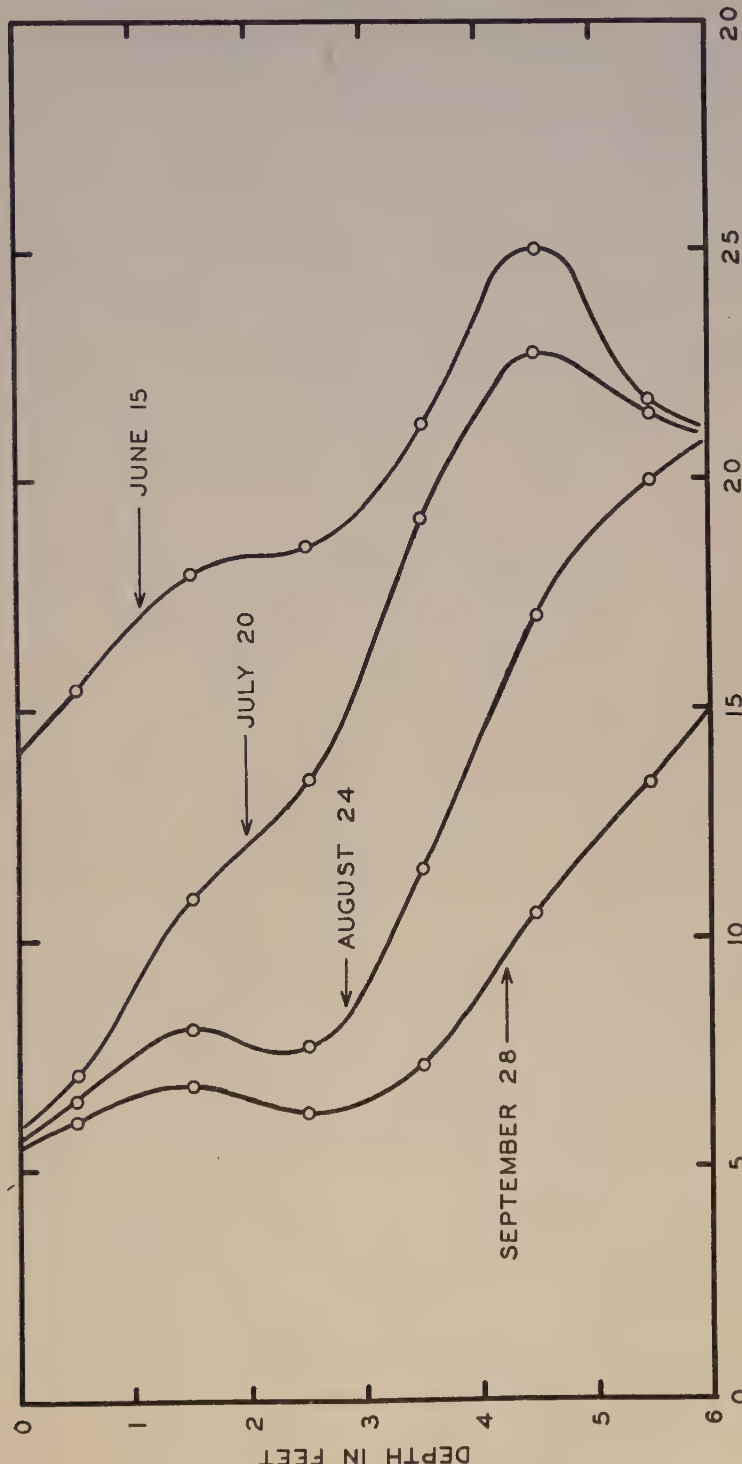

FIGURE 6. Moisture contents of the soil in the non-irrigated plot in the Croil orchard at four different dates in 1950. The moisture content is plotted at the central point of each foot of depth, to a total depth of six feet. This chart illustrates the variation in rate of consumptive use of water at each soil depth as the season progressed.

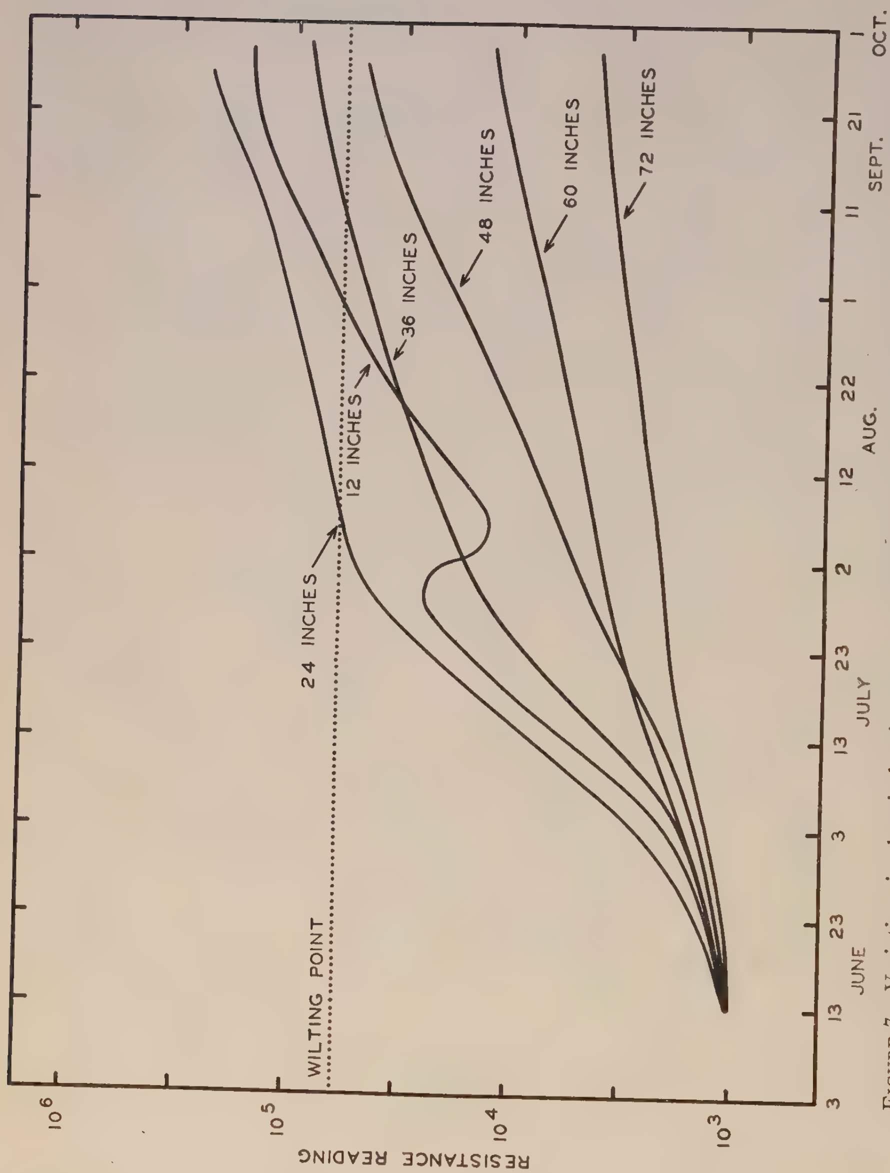

FIGURE 7. Variations in electrical resistance readings at depths of 12 to 72 inches in the non-irrigated plot in the Croil orchard. Resistance readings were recorded in ohms, using Bouyoucos gypsum blocks at the depths noted. The permanent wilting point is assumed to be represented by a resistance of 75,000 ohms. Rains occurred late in July.

The Bouyoucos gypsum block readings are charted in Figure 7. Most of the blocks had normal readings of around 1000 ohms at field capacity; accordingly, all readings were corrected in such a manner that they would be 1000 on June 13, the first day of reading. This ensured that the curves would all start at the same point on the chart. The soil at 12 inches depth was affected by the heavy rains, and so the 12-inch curve is irregular. The curves for the other depths, however, are reasonably regular. It will be noted that with the exception of the 12-inch curve, the soil dried out progressively more slowly with greater depth. Assuming that a resistance of 75,000 ohms represents the permanent wilting point, the soil at a depth of 24 inches reached this point about August 6, that at 12 inches about August 30, and that at 36 inches about September 8. On September 28, the last day of sampling, the soil at 48 inches had almost reached the wilting point. Below 48 inches, however, the soil was still relatively moist at that time. The curve at 84 inches was practically the same as that at 72 inches, and so was omitted from the chart.

DISCUSSION

The effect of depth in the soil on the rate of consumptive use of water has a direct bearing on the depth of irrigation required. In this investigation, consumptive use was greatest in the top foot, and lessened successively with each foot increase in depth. In some cases it lessened to zero before reaching six feet. In most cases there was still some consumptive use at six feet, though usually it was of little practical importance below four feet. This meant that below four feet the soil was almost always still quite moist at time of irrigating. It appears from this that where a regular supply of irrigation water is available, it should be sufficient to irrigate a mature orchard to a depth of four feet. The gravitational water present in the top four feet of soil when an irrigation is stopped should be sufficient to maintain adequate moisture in the soil below this depth.

Irrigation tests have been made in orchards, using soil moisture indicators at varying depths. Tests have also been made in which an auger or shovel has been used to determine the depth of irrigation. The results of these tests will be reported elsewhere. It should be noted here, however, that irrigating mature orchards to a depth of four feet at regular intervals has proved sufficient to maintain adequate soil moisture throughout the whole root area. In some cases, less than four feet has proved sufficient; such, for example, as with shallow soils underlaid by gravel; or where a water table is present in the lower root area; or where the trees are not yet full-grown.

The results of the investigations in the Croil and Stevens plots indicate that the above finding, i.e. that consumptive use decreases with depth, holds true only when the soil is not allowed to dry too much. When no irrigation water was applied, the top soil dried out more rapidly than the lower soil early in the season, but the reverse held true later in the season. The results obtained appear to justify the following conclusions:

(1) Immediately following an irrigation, apple trees can obtain their water requirements more easily from the top foot of soil than at lower depths. This is possibly due to a higher concentration of fibrous roots,

better aeration, and warmer soil temperatures in the top two feet than at lower depths, as suggested above in the "Review of Literature". As a result, the rate of consumptive use is initially much greater near the surface and lessens with depth. In addition, the consumptive use in the top six inches is increased greatly by evaporation from the surface of the soil.

(2) As the soil in the top two feet dries out, it becomes more and more difficult for the roots to absorb moisture from this part of the soil. A greater pressure deficiency for moisture develops within the plant cells and conducting tissues, and this is transferred to absorbing roots deeper in the soil. This in turn causes an increase in rate of consumptive use below the top two feet. Thus a reduction in consumptive use in the upper soil is accompanied by an increase in consumptive use in the lower soil.

(3) This process is continued as more and more soil dries out. The top foot of soil dries out to the permanent wilting point, followed in turn by the second, third and fourth feet. The point is finally reached where the roots are not able to absorb water fast enough to keep up with transpiration, and the plant wilts.

The question arises as to when, in this process of drying out of the soil, the plant first suffers harmful effects from lack of water. It is claimed by some workers (10) that harmful effects occur before the permanent wilting point is reached, and by others (14) that there are no measurable harmful effects until the plants wilt. Good evidence has been presented by many workers to support both points of view. This problem has been studied in the Croil and Stevens plots, and the results obtained will be reported elsewhere. Suffice it to say here that harmful effects on the trees were obtained before the end of the tests, at which time all of the soil in the root area had not yet been reduced to the permanent wilting point.

As noted above in the "Review of Literature", some workers (13, 17) have found that the rate of consumptive use in orchard soils may vary little from the surface downward for several feet. This finding is quite different from that found in the 41 plots in the consumptive use studies reported in this investigation. Had these 41 plots not been irrigated, however, the total consumptive use for the season would probably have been about the same in the fourth and fifth feet of soil as in the first foot. This can be seen from the results reported above on the Croil plot, which was not irrigated. By September 28, even this heavy silt soil was reduced to the wilting point in the top three feet, and was almost at the wilting point in the fourth foot. Had there been no rainfall during the season, there would have been little difference in rate of consumptive use between the first foot and the fourth foot for the season as a whole. Under normal irrigation practices, however, the fact remains that the rate of consumptive use is greatest in the top foot and decreases progressively with an increase in depth.

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FERTILITY STUDIES ON SOIL TYPES

II. THE PHYSICAL AND CHEMICAL COMPOSITION OF SOILS FROM CARLETON AND GRENVILLE COUNTIES IN ONTARIO[1]

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ABSTRACT

The results of analysis of 90 surface soil samples from ten major soil types of Carleton and Grenville counties in Ontario are presented. These results should apply in general to the soils of most of Eastern Ontario. The samples varied in texture from sands to clays and in reaction from moderately acid to moderate alkaline. Except for the soils of light texture, most of the samples were quite well supplied with organic matter and nitrogen. Values for exchangeable calcium, magnesium and potassium are given.

Results for the trace elements boron, manganese, cobalt and copper showed the variation to be found between and within soil types. This is the first time such information has been available for any area in Canada. A high positive correlation was found between clay and cobalt content and between clay and copper content.

The soils in the county of Carleton in the province of Ontario were surveyed during 1940 and the results were published in March, 1944 (5). The soils in Grenville county, which lies to the south of Carleton, were surveyed during 1945 and the results were published in 1949 (11). In 1946, a comprehensive greenhouse and laboratory investigation of the fertility of the surface soil of some of the more important soil types was undertaken and an outline of the general procedure was given in an earlier paper (9). In each of three successive years, 30 surface soil samples, representing three farms selected more or less at random with respect to management practices, on each of 10 soil types were studied. On these 90 samples a considerable amount of data has been accumulated with respect to response to fertilization as measured by yield increases and plant composition, as well as with respect to the relationship between the so-called availability of certain plant nutrients as measured by laboratory methods, their uptake by the plants and crop response to applied fertilizer. It is planned to summarize these data and present them in a series of papers and the purpose of this article is to serve as an introduction to the subsequent material by giving information on the physical and chemical composition of the soils under investigation.

The soil types from which surface samples were obtained have been fully described elsewhere (5, 11) but, for convenience, the following brief description is given: (1) *Uplands sand*, an excessively drained, thin podzol; (2) *Rubicon loamy sand*, an imperfectly drained podzol developed on an undulating plain; (3) *Kars gravelly sandy loam*, an excessively drained, weakly developed, grey brown podzolic soil on gravelly ridges; (4) *Manotick sandy loam*, a brown podzolic soil developed on an undulating clay plain which has been covered by layers of fine sand and silt of varying depth, with the result that the cultivated layer may be rather variable in texture;

[1] Joint contribution from the Division of Chemistry, Science Service, and the Division of Field Husbandry, Soils and Agricultural Engineering, Experimental Farms Service. Scientific Contribution No. 224, Division of Chemistry.
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TABLE 1.—MECHANICAL COMPOSITION

Type	Sand (2.0–0.05 mm.)		Silt (0.05–0.005 mm.)		Clay (<0.005 mm.)	
	Mean	S.E.*	Mean	S.E.*	Mean	S.E.*
	%		%		%	
Uplands sand	87.0	2.0	7.9	1.7	5.1	0.7
Rubicon loamy sand	79.1	3.2	14.6	9.0	6.3	0.8
Kars gravelly sandy loam	71.2	7.1	16.1	3.9	12.7	3.6
Manotick sandy loam	55.6	13.4	31.1	11.6	13.3	4.3
Castor silt loam	49.5	7.3	39.0	6.1	11.5	2.5
Grenville loam	49.3	9.1	29.4	5.1	21.3	5.2
Osgoode loam	44.0	15.2	38.8	10.7	17.2	4.7
Carp clay loam	29.7	5.4	38.4	4.1	31.9	3.7
North Gower clay loam	27.5	5.7	43.4	4.5	29.2	2.6
Rideau clay	23.7	5.2	30.0	5.5	46.3	6.8

* S.E. = Standard error of mean of 9 farms (P .05).

(5) *Castor silt loam*, a dark grey gleisolic soil subject to a fluctuating water table; (6) *Grenville loam*, a well drained brown forest soil on till; (7) *Osgoode loam*, a dark grey gleisolic soil frequently occupying poorly drained basins between ridges of till; (8) *Carp clay loam*, a dark grey gleisolic soil with moderate to imperfect drainage; (9) *North Gower clay loam*, a poorly drained dark grey gleisolic soil; (10) *Rideau clay*, a very heavy, moderately drained, dark grey gleisolic soil. All these soils, with the exception of the Grenville, are of alluvial or lacustrine origin.

Samples of the surface soil of the various soil types were obtained to a depth of approximately 6 inches, each sample being a composite from 20 or more sampling points in a field. The fields selected on any soil type were considered to include a range in fertility in accordance with management, the only restriction being that fields heavily manured in the year of sampling were avoided. All samples from Castor silt loam, Carp clay loam, North Gower clay loam and Rideau clay were obtained from farms located in Carleton county, whereas the samples from the other soil types were procured from sites distributed over Carleton and Grenville counties. In selecting fields for sampling, an attempt was made to include sites representative of rather extensive and well distributed areas of the soil types under study. Thus, although it would have been possible to obtain samples from a particular soil type more uniform in respect to each other and to the modal concept of the type, it was considered that the procedure followed provided an opportunity for studying the range of soil properties found within a soil type.

Mechanical Composition

The mechanical composition of the soil samples as determined by the Bouyoucos hydrometer method (4) is presented in Table 1. For each soil type the mean of nine samples is given, together with the standard error of the mean of nine samples at P .05, the estimate of error being based on the variation between samples from the same soil type. On the basis of the samples obtained, only 5 out of 100 times would a mean value for nine samples be expected by chance to deviate from the means reported by more than $\pm$ the standard errors recorded.

The samples from areas mapped as Manotick sandy loam and Osgoode loam varied considerably from farm to farm as shown by the relatively high standard errors for sand and silt. This might be expected since the Manotick sandy loam was mapped as a soil complex and the Osgoode loam consists of a combination of marine clay and material of lighter texture washed in from adjoining areas. The variations in silt content of samples from sites on Rubicon loamy sand and in the sand content of samples from the Grenville loam areas were relatively high.

In most instances the mean values for mechanical composition of the samples from a particular soil type did not deviate greatly from the values characteristic of the textural class indicated by the soil type. The texture of the samples of Castor soil approached that of a sandy loam rather than a silt loam; however the sand in this soil was observed to be fine in character.

Chemical Composition

The chemical composition of the soil samples is presented in Tables 2 and 3. The results in Table 2 are for reaction, loss on ignition, nitrogen,

TABLE 2.—CHEMICAL COMPOSITION

Type	pH		Loss on Ign.		Nitrogen(N)		Phosphorus(P)		Exchangeable Bases					
									Calcium(Ca)		Magnesium(Mg)		Potassium(K)	
	Mean	S.E.*	Mean	S.E.*	Mean	S.E.*	Mean	S.E.*	Mean	S.E.*	Mean	S.E.*	Mean	S.E.*
	%		%		%		%		me.		me.		me.	
Uplands sand	6.1	0.45	2.98	0.76	0.11	0.037	0.07	0.019	3.04	1.64	0.63	0.52	0.14	0.04
Rubicon loamy sand	6.8	0.65	4.95	0.90	0.19	0.028	0.08	0.024	7.62	2.82	1.03	0.27	0.10	0.03
Kars gravelly sandy loam	6.8	0.51	5.07	1.09	0.20	0.050	0.09	0.018	7.50	2.32	1.34	0.48	0.13	0.03
Manotick sandy loam	6.7	0.40	4.95	0.60	0.21	0.024	0.09	0.019	9.43	3.32	1.62	0.49	0.17	0.03
Castor silt loam	7.0	0.56	4.37	1.35	0.16	0.045	0.10	0.021	8.62	3.46	1.78	0.48	0.11	0.02
Grenville loam	7.7	0.25	5.92	0.75	0.25	0.039	0.08	0.016	12.87	2.57	3.36	0.89	0.20	0.06
Osgoode loam	7.5	0.52	5.26	0.81	0.22	0.034	0.10	0.010	15.15	3.90	2.47	0.91	0.14	0.04
Carp clay loam	7.1	0.27	7.78	0.94	0.35	0.055	0.12	0.014	21.21	2.78	2.99	0.51	0.35	0.11
North Gower clay loam	7.4	0.38	7.60	1.13	0.31	0.041	0.11	0.008	21.60	3.00	3.04	0.59	0.32	0.16
Rideau clay	6.3	0.32	6.60	0.90	0.24	0.042	0.10	0.011	15.97	5.28	3.92	0.65	0.58	0.20

*S.E. = Standard error of mean of 9 farms (P .05).

TABLE 3.—TRACE ELEMENT CONTENT

(as p.p.m. of the element)

Type	H_2O-sol. Boron		Total Manganese		Exchangeable Manganese		Eas. Red. Manganese		Total Cobalt		Total Copper	
	Mean	S.E.*	Mean	S.E.*	Mean	S.E.*	Mean	S.E.*	Mean	S.E.*	Mean	S.E.*
Uplands sand	0.22	0.062	530	170.8	2.5	1.11	86.6	41.6	3.4	0.66	5.9	2.53
Rubicon loamy sand	0.37	0.067	255	56.0	3.5	0.95	30.6	18.1	3.1	0.60	3.5	0.69
Kars gravelly sandy loam	0.42	0.113	1308	190.1	5.5	2.52	283.0	44.9	7.1	1.17	11.1	3.05
Manotick sandy loam	0.47	0.091	432	109.3	3.3	1.06	44.3	25.9	5.5	1.28	14.3	2.60
Castor silt loam	0.41	0.111	372	33.7	4.6	2.46	22.2	15.5	4.6	0.72	8.2	2.61
Grenville loam	0.46	0.038	1196	233.9	3.8	2.79	327.6	81.6	8.2	1.15	7.7	2.98
Osgoode loam	0.58	0.125	407	122.8	4.8	2.29	40.2	19.6	6.3	1.42	10.8	3.52
Carp clay loam	0.79	0.136	679	65.9	5.3	3.04	86.1	20.2	10.7	1.19	23.6	2.77
North Gower clay loam	0.76	0.185	605	106.8	4.9	1.88	71.1	27.7	8.9	0.92	17.8	2.30
Rideau clay	0.49	0.163	828	80.0	5.4	1.92	79.0	18.1	16.4	2.67	23.8	6.53

* S.E. = Standard error of mean of 9 farms (P .05)

phosphorus and the exchangeable cations calcium, magnesium and potassium; those in Table 3 are for the trace elements boron, manganese, cobalt and copper. The methods employed were those in common use by the Division of Chemistry (13).

Most of the samples from the Uplands, Rubicon, Kars, Manotick and Rideau types were slightly to moderately acid and most from the Grenville, Osgoode, Carp and North Gower types were neutral to mildly alkaline. The nine Castor samples varied from moderately acid to moderately alkaline. The samples of Grenville, Carp and Rideau soils were relatively uniform in reaction from farm to farm on the same soil type.

The results for loss on ignition and nitrogen give a good indication of organic matter levels. Data collected over many years have indicated that the majority of Canadian soils with the exception of the chernozems and the organic soils contain between 0.10 and 0.30 per cent nitrogen (1). As shown by the data in Table 2, the surface samples from Castor silt loam, an imperfectly drained soil, were relatively low in nitrogen, the mean value being only slightly higher than that for Uplands sand, an excessively drained soil. The samples of Carp and North Gower soils were relatively high in nitrogen content, those from Rideau clay being somewhat lower.

In general the soils under discussion were well supplied with phosphorus. The total phosphorus in Canadian soils of average fertility usually lies between 0.05 and 0.11 per cent P but some loams contain up to 0.13 per cent (1). The samples from the Osgoode loam, Carp clay loam, North Gower clay loam and Rideau clay soil types tended to be more uniform in total phosphorus content.

The exchangeable cations were obtained by extraction and leaching with neutral normal ammonium acetate solution. In the case of those samples containing free calcium carbonate, the results for calcium were probably high due to the solubility of $CaCO_3$ in the ammonium acetate solution. The amounts of exchangeable calcium and magnesium in general increased with the pH values of the samples but were also affected by texture (amount of clay present) and organic matter content. Values for exchangeable calcium ranged from 1.3 to 30.2 milliequivalents and those for exchangeable magnesium from 0.15 to 5.20 milliequivalents per 100 gm. of air-dry soil. The levels of exchangeable potassium showed some relationship with texture, high values being found almost entirely in the clay loams and clays. Values ranged from 0.04 to 0.98 milliequivalents per 100 gm. The samples from the Carp clay loam, North Gower clay loam and Rideau clay varied considerably in respect to exchangeable potassium from farm to farm on the same soil type.

Trace Elements

The water-soluble boron content (Table 3) varied from 0.13 to 1.17 p.p.m. B. Investigations conducted in this laboratory during the past 15 years have indicated that soils containing approximately 0.4 to 0.6 p.p.m. water-soluble boron have satisfactory levels of this element. On this basis, approximately one-third of the samples examined could be considered low in this constituent and most of these were found in the Uplands, Rubicon, Kars, Castor and Rideau types.

In the case of manganese, in addition to the total amount present, the amounts found in exchangeable and in easily-reducible forms were determined. The types with the highest total manganese content were the Kars and Grenville and these also had by far the largest amounts in an easily-reducible condition. The availability of manganese is greatly influenced by soil reaction and decreases with increasing pH values. Work conducted in Australia (8) has indicated that alkaline soils having less than 15 p.p.m. of easily reducible manganese would be deficient for plant growth. Investigations in the United States (12) showed that if soils which were slightly acid to alkaline in reaction had less than 25 p.p.m. of easily reducible manganese dioxide (16 p.p.m. Mn), they would not supply plants with sufficient manganese for normal growth. Manganese deficiency in oats was observed on only one soil during the first year of cropping in the greenhouse but two or three other cases were suspected where cropping was continued for two or more years.

Total amounts of cobalt ranged from 2.0 to 22.8 p.p.m. Co and the largest amounts were found in the heavier-textured soils. The correlation coefficient between clay and cobalt content was +0.938. Plants are apparently not affected by low supplies of cobalt (3) but cobalt deficiency symptoms may develop in animals which feed on crops containing too little of this element. In a study of the cobalt status of New Zealand soils (7), values of 6 to 20 p.p.m. Co were associated with soils on which deficiency of this element did not occur, whereas soils on which the disease was found were much lower, many samples containing less than 2.0 p.p.m. Co. In England (10), cobalt soluble in concentrated hydrochloric acid averaged 4 p.p.m. Co for unhealthy soils and about 20 p.p.m. for healthy soils. Examination in this laboratory of a soil from Cape Breton county, Nova Scotia, where a deficiency of cobalt was suspected, showed a total cobalt content of 2.7 p.p.m. while a sample representing an area considered to be satisfactory showed a content of 8.9 p.p.m. Co. Although cobalt deficiency symptoms in live stock have been reported in Nova Scotia, Quebec and Alberta, they do not appear to be prevalent in Carleton and Grenville counties in Ontario.

Total amounts of copper ranged from 1.9 to 39.4 p.p.m. Cu and as with cobalt, the clay loam and clay soils contained higher levels than the soils of lighter texture. The correlation coefficient between clay and copper content was +0.863. Little information is available in the literature on which to base an estimate of what might be considered a sufficient amount of copper in a soil. In 1943, Holmes (6) presented data on the total amount of copper in soil profiles widely distributed in the United States. Values from 2 to 111 p.p.m. Cu were found. Workers in Florida (2) obtained a mean value of 3.82 p.p.m. Cu in soils from deficient areas and 7.20 p.p.m. Cu in those from healthy areas. Although symptoms of copper deficiency have been reported as occurring on minerals oils in other countries, in Canada copper deficiency is usually associated with crops grown on organic soils.

DISCUSSION OF RESULTS

The information contained in the foregoing, together with the results presented in the soil survey reports, gives a general picture of the chemical and mechanical composition of the soils of Carleton and Grenville counties and of the variations that can be expected between, as well as within, soil types. It is believed that these results will apply to the soils of most of Eastern Ontario. Where information was comparable (sand, silt, clay, reaction, organic matter levels and exchangeable calcium and potassium), similar ranges were found in the soil survey reports and in the results presented herein. As would be expected with such a variety of soil types, samples varied in texture from sands to clays and in reaction from moderately acid to moderately alkaline. The organic matter content showed a similar wide variation but the majority of the samples could be considered to be reasonably well supplied.

The samples examined contained satisfactory amounts of total phosphorus. No results for readily-soluble phosphorus have been presented. A large number of methods have been proposed for the determination of so-called available phosphorus and results vary widely depending on the extractant used and other factors. Several such methods have been studied in this investigation and, in a subsequent paper, the results obtained by them will be discussed in relation to uptake of phosphorus and yield increases from applied phosphorus. Similarly results obtained by a number of methods for measuring the availability of potassium will be presented and discussed in relation to crop response to applied potassium.

Information on the trace element content of Canadian soils is becoming of increasing importance as new areas of deficiency of one or more of this group of essential plant constituents are detected almost every year. Data on the variations that normally occur in the amounts of these elements have not been reported previously for any area in Canada. A considerable amount of work has been done in this laboratory on the relationship between water-soluble boron in soils and boron deficiency diseases in crops. Not enough work of this nature has been conducted with the other trace elements to indicate levels of deficiency or sufficiency.

SUMMARY

The results of analysis of 90 surface soil samples representing ten major soil types of Carleton and Grenville counties in Ontario, have been presented. The soils varied in texture from sands to clays and in reaction from moderately acid to moderately alkaline. Except for the soils of light texture, most of the samples were quite well supplied with organic matter, nitrogen and phosphorus.

Results for the trace elements boron, manganese, cobalt and copper showed the variation to be found between and within soil types. This is the first time such information has been available for any area in Canada.

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ARTIFICIAL DEFOLIATION OF FIELD BEANS[1]

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ABSTRACT

Tests conducted in the field during the 1949, 1950 and 1951 seasons proved that it is possible and practical to hasten the maturity of field beans by the use of chemical defoliants.

Monosodium cyanamid (X5) and ammonium thiocyanate at 30 lb./ac. and 12.5 lb./ac. respectively, produced excellent defoliation and hastened the maturity by about a week to 10 days.

Results indicated that too early an application of defoliant may cause considerable reduction in yield and weight per thousand seeds.

Defoliation does not affect the degree of shattering or shelling during the pulling operations and no differences in threshing efficiency were noted.

The harvesting of field beans is often difficult until after a light frost has occurred. The leaves and stems remain succulent, thus delaying maturity, and the season may advance into a period of bad weather. For this reason a high quality seed is not easily produced. Frequently, maturity is late in low areas of a field, making combine harvesting operations almost impossible. With certain crops maturity can be advanced by the use of chemicals for defoliation, and investigations on this procedure with field beans were conducted on field plots at the Central Experimental Farm, Ottawa, Canada, in the period 1948–51, inclusive.

The use of chemicals to defoliate the bean crop originated from their use in inducing cotton plants to shed their leaves. Tharp (2), at the Arkansas Experimental Station, points out that artificial defoliation of cotton hastens boll ripening and aids the mechanical harvesting of the crop. Carlyle (1) has successfully applied the principle to soybeans. He finds that earlier harvesting is possible, thus reducing losses from shattering and producing higher yields. Also, a better quality of uniform soybean seed is produced. In addition special reference is made by Carlyle to the advantage of using chemical defoliants on weedy crops, since they hinder the weeds from going to seed, thus limiting the spread of the weed population.

MATERIALS AND METHODS

The various chemicals that were investigated differed in type, formula, and method and rate of application. Certain chemicals were applied as a spray while others were used as a dust. In Table 1 are cited the different chemicals, their nature of application and rates per acre. The dusts were applied with a hand operated duster, and the sprays with a knapsack sprayer. All chemicals that were applied as sprays proved readily soluble. In these tests no wetting agents were added to the spray solutions.

The defoliants were applied at two stages of growth: (1) pods well formed, and leaves quite green; (2) pods somewhat green but the lower leaves beyond the yellowing stage. The moisture contents of the pods at

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TABLE 1.—CHEMICALS USED FOR DEFOLIATION OF BEANS, TYPE AND RATE PER ACRE OF APPLICATION, AND NUMBER OF YEARS TESTED

Chemical	Type of application	Rate per acre	Years tested
Calcium cyanamid*	Dust	100 lb.	1948–51
Monosodium cyanamid (X10)*	"	90 "	"
" " (X5)*	Spray	60 " /60 gal. water	"
Potassium cyanate	"	16 " /80 " "	"
Ammonium thiocyanate (1)	"	7.5 " /20 " "	1950–51
" " (2)	"	10.0 " " " "	"
" " (3)	"	12.5 " " " "	"
" " (4)	"	15.0 " " " "	"
" " (5)	"	20.0 " " " "	"
Dinitro weed killer (1)	"	3 gal./100 gal. water	1951
" " " (2)	"	4 " " " "	"
2,4-D (Amine) (1)	"	4 oz. acid equivalent	1949
" " (2)	"	8 " " "	"

* Trade name of products of North American Cyanamid Limited.

these two stages were approximately 71 per cent and 17–25 per cent respectively. The interval between the two periods of application varied for the different years, depending on the effect of the climatic conditions on the age of the plants. In 1949 the interval between the first and second application was one week, because the weather conditions aged the plants very quickly. In 1950, the plants did not advance in age as quickly, and the interval between the applications was approximately two weeks. The following year, 1951, the second application was applied nearly three weeks after the first. The respective application dates in each year are given in Table 2.

TABLE 2.—CALENDAR DATES WHEN DEFOLIANTS WERE APPLIED DURING THE YEARS 1949–51, INCLUSIVE

Year	First application	Second application
1949	August 11	August 18
1950	" 17	September 1
1951	" 23	" 13

The experimental investigations were conducted on an acre plot of Clipper beans. The rate of seeding was 45 lb. per acre in rows spaced 28 inches apart. Prior to the dates of application the field area was sectioned into plots, which were staked out accordingly with large sized stakes. Each plot consisted of 8 rows, 24 feet long, and the plots were separated by at least one row of beans. All treatments were in duplicate in each date of application. The six inside rows of each plot, $16\frac{1}{2}$ feet in length, were harvested for yields.

RESULTS AND DISCUSSION

Defoliant Dusts

Calcium Cyanamid: This chemical was applied as a dust at the rate of 100 lb./ac. The effect on the plants is not so immediate as with some of the other chemicals. This is partly due to the fact that moisture is

TABLE 3.—RATE OF INDUCED EARLINESS IN PLANT MATURITY OF THE VARIOUS TESTS IN RELATION TO THE CHECK PLOT, MEASURED BY NUMBER OF DAYS

Treatment	First application			Second application		
	1950	1951	Av.	1950	1951	Av.
Dust						
Calcium cyanamid	4.6	10.0	7.2	4.5	2.0	3.2
Monosodium cyanamid (X10)	2.0	8.0	5.0	2.5	5.0	3.7
Spray						
Monosodium cyanamid (X5)	15.0	11.5	12.7	7.0	8.0	7.5
Potassium cyanate	7.5	7.5	7.5	7.0	.5.5	6.2
Ammonium thiocyanate[1]						
(1)	8.5	2.5	5.5	—	1.0	—
(2)	11.0	8.5	9.7	—	1.0	—
(3)	15.0	10.5	12.7	7.0	3.0	5.0
(4)	—	9.5	—	7.0	2.0	4.5
(5)	—	8.5	—	7.0	2.0	4.5
Dinitro weed killer[2]						
(1)	—	1.5	—	—	—	—
(2)	—	0.0	—	—	—	—
Check	0.0	0.0	0.0	0.0	0.0	0.0
Maturity of check plots	Sept. 22	Sept. 15		Sept. 22	Sept. 18	

[1] and [2] The rates of application are cited in Table 1.

essential for the calcium cyanamid to cause partial hydrolysis. If there is no moisture, no foliage injury or defoliation will result. Therefore, it should be applied in the evening or early morning while the dew is still present on the leaves. An even distribution is difficult to obtain, but it is essential when using a dust or a spray that the chemical reach all the leaves. The maturity of the plants dusted with this chemical, as shown in Table 3, averaged approximately 3–7 days earlier than the checks. In Table 4, it will be observed that the yields were less than the checks by more than 5 bushels in the first application. Later applications resulted in lower yields in 1950 and higher yields in 1951. The seed weights given in Table 5 for the calcium cyanamid treatments were less affected by this chemical than by some of the others.

Monosodium Cyanamid (X10): Application of this chemical dust was made at the rate of 90 lb./ac. Unlike calcium cyanamid, this defoliant does not require moisture for the defoliant reaction, hence artificial defoliation is more certain to take place. In 1950, the treated plots of both applications were two days earlier than the check and 5–8 days earlier in 1951. Since monosodium cyanamid (X10) is slower in its reaction than the other chemicals used, the yields and seed weight were less affected by its use.

Defoliant Sprays

Monosodium Cyanamid (X5): This chemical, containing 65 per cent active ingredient is soluble. Applied as a spray it appeared to be definitely superior to all others in checking leaf growth. Premature death of the leaves occurred 3–4 days after treatment. However, the leaves had a tendency to remain attached to the plant, even beyond the maturity stage.

TABLE 4.—YIELDS OF EACH TREATMENT IN THE FIRST AND SECOND APPLICATION TESTS OF 1950–51*

Treatment	First application			Second application		
	1950	1951	Av.	1950	1951	Av.
Dust						
Calcium cyanamid	27.7	37.8	32.7	32.3	48.1	40.1
Monosodium cyanamid (X10)	29.6	43.2	36.4	25.9	46.1	35.5
Spray						
Monosodium cyanamid (X5)	10.9	27.0	18.9	29.3	50.4	39.8
Potassium cyanate	19.5	41.6	30.5	36.1	46.1	41.1
Ammonium thiocyanate						
(1)	19.9	45.3	32.6	—	48.8	—
(2)	22.3	43.5	32.9	—	42.8	—
(3)	23.1	44.6	33.9	34.8	52.1	43.4
(4)	—	41.6	—	50.7	44.1	37.4
(5)	—	37.9	—	20.4	50.3	35.3
Dinitro weed killer						
(1)	—	43.6	—	—	—	—
(2)	—	47.4	—	—	—	—
Check	32.8	43.0	37.9	34.5	43.6	39.0

* 1949 crop was severely injured with hail at time of maturity; hence yields were not possible.

TABLE 5.—WEIGHT OF SEED IN GRAMS PER THOUSAND SEEDS OF EACH TREATMENT IN THE FIRST AND SECOND APPLICATION TESTS 1949–51

Treatment	First application				Second application			
	1949	1950	1951	Av.	1949	1950	1951	Av.
Dust								
Calcium cyanamid	190.4	243.5	234.0	227.4	216.2	244.0	250.0	234.4
Monosodium cyanamid (X10)	191.3	262.2	234.5	226.1	204.0	236.7	243.5	225.8
Spray								
Monosodium cyanamid (X5)	195.0	222.7	218.5	213.7	206.9	237.0	236.2	224.4
Potassium cyanate	200.0	224.0	230.7	215.8	204.2	239.5	232.7	223.2
Ammonium thiocyanate								
(1)	—	218.5	234.7	—	—	—	228.2	—
(2)	—	221.0	234.0	—	—	—	231.2	—
(3)	—	233.7	231.0	—	—	235.5	247.5	—
(4)	—	—	220.0	—	—	226.0	235.7	—
(5)	—	—	229.0	—	—	215.0	241.2	—
Dinitro weed killer								
(1)	—	—	230.5	—	—	—	—	—
(2)	—	—	242.2	—	—	—	—	—
2,4-D								
(1)	194.3	—	—	—	204.0	—	—	—
(2)	194.3	—	—	—	202.6	—	—	—
Check	194.5	253.0	240.2	230.0	213.4	252.5	255.0	237.9

Maturity of the plants in the plots treated with this chemical was approximately two weeks earlier than the check in the first application in both years, and about a week earlier in the second application. Although earlier maturity was induced, yields were affected considerably in the first application of both years (1950–51), and in the second application of 1950. Generally, the seed weight of the treated plants was less than the check.

In another investigation it was found that application rates of 30 and 60 lb./ac. were equally as effective for defoliation as the 90 lb./ac. rate. The latter was advantageous only when adverse weather conditions induced mild regrowth with the lower rates of application.

Potassium cyanate; Very noticeable effects were produced with potassium cyanate shortly after treatment, especially with the first application. The leaves of the plants were beyond the wilting stage about 1–2 days after the application. The maturity occurred approximately a week before the check. Although there was some pod burning, the yield of seed was not appreciably affected, except in the first application test of 1950. Generally, the seed weight was less than the check.

Ammonium thiocyanate: Rates of application from 7.5 lb. to 20 lb. per acre produced very favourable results. The best reaction occurred at the application rate of 12.5 lb./ac. In 1950–51, the plots treated at this rate in the first application were 10–15 days earlier than the check plots and 3–7 days earlier in the second application. Also, at this rate the yields were equally as high as the lower application rates and generally higher than for the heavier applications. No damage or discoloration of the pods occurred at any of the rates used.

Dinitro weed killer: Two rates of application were used. It was apparent that neither of the rates was satisfactory as a defoliant. The leaves showed no worthwhile injury and there was no appreciable speeding up of maturity. It would appear that much heavier rates of application of this chemical would be required for its use as a defoliant for field beans.

2,4-D: The amine form of this weed spray was investigated for use as a defoliant in only one season, 1949. Both the 4- and 8-oz. rates of application were effective in killing the leaves, but the reaction was comparatively slow. It did not prove very satisfactory because generally all the leaves remained attached to the plant thus slowing up the action of the sun in drying out the plants.

EFFECT OF DEFOLIATION ON RATE OF RIPENING OF SEED

This investigation was conducted as a separate study during the growing seasons of 1950–51. The defoliant monosodium cyanamid (X5) was sprayed at 30, 60 and 90 lb./acre at two stages of maturity. The first stage was applied when the pods were in the early ripening period and the second application when 50 per cent of the pods were ripe. Samples of threshed beans were taken every two days for moisture determinations.

The 1950 data illustrated in Figure 1A show that there was a more rapid decline in the moisture level of the bean seeds of the treated plants than in the checks. The first application indicates that the moisture of the bean seeds was near 20 per cent at approximately two weeks after the application date, at which time the checks were at the 45 per cent moisture level. The treated bean crop could have been harvested shortly after this period if a rain had not intervened. Although the rain reduced the advantages gained by the defoliation, the treated plots were ready to harvest earlier than the checks. The second application followed a similar course to that of the first, as shown in Figure 1A.

The weather conditions during 1951 induced very early maturity of the crop. In Figure 1B, the results indicate that the treated plants were only slightly lower in moisture than the check at approximately three weeks after the first application.

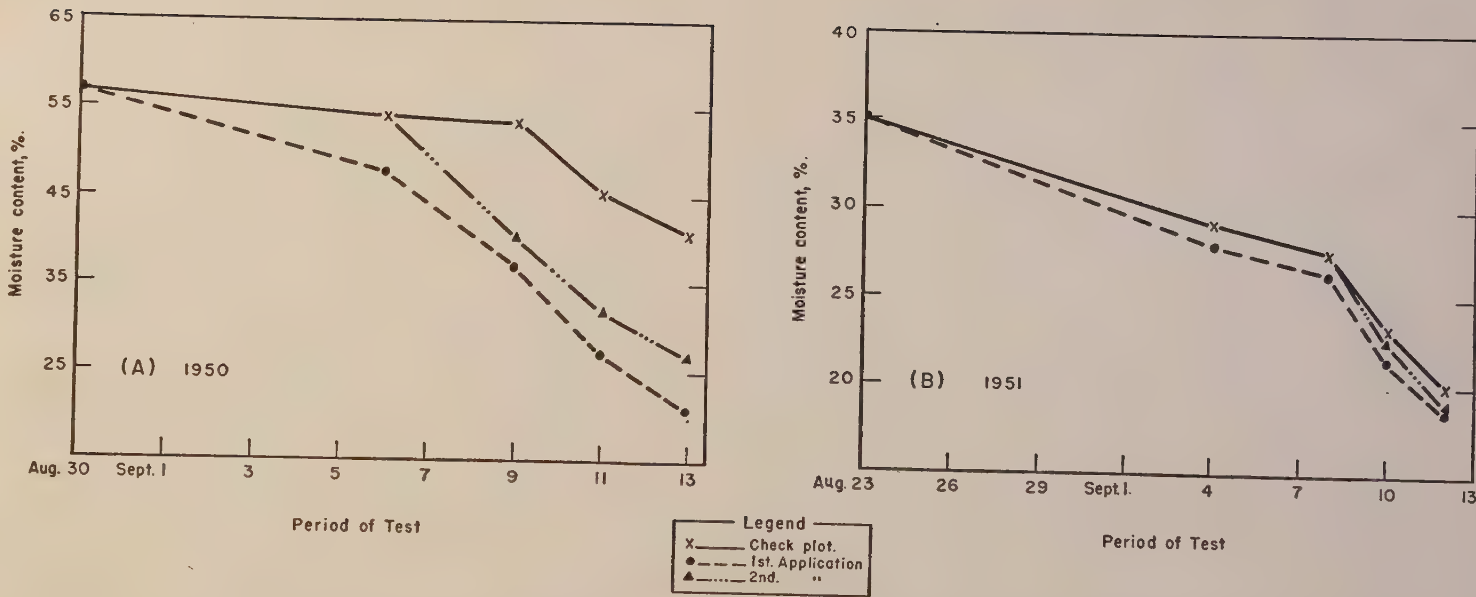

FIGURE 1A AND B. Rate of loss of moisture in the seed of field beans from two dates of application of monosodium cyanamid (X5) in 1950 and 1951.

CONCLUSIONS

Two chemical dusts and four chemical sprays were applied to field beans at two stages of maturity to induce artificial defoliation. The moisture level of the beans was followed as a means of indicating how soon the crop might be combined.

Monosodium cyanamid (X 5) at the rate of 30 lb./ac., and ammonium thiocyanate at 12.5 lb./ac. applied as a spray, produced excellent defoliation. At these rates the results denoted that defoliation was more thorough and maturity more advanced than with other applications. Recent information has indicated that the addition of a spreading agent lowers the amount of chemical required to produce similar results. Dinitro weed killer and 2,4-D did not prove effective as defoliants in these experiments.

Chemical defoliation of the bean crop will be governed by the type of season and growth of the crop. A more luxuriant growth in 1950 than in either 1949 or 1951 permitted the treatments to be more effective in hastening maturity. In 1951 the crop matured rapidly and under normal conditions a defoliant was not necessary. Defoliation should be very effective in fields having late maturing pockets or low lying areas as a means of producing uniform ripening. In an average year the date for combining might be advanced by about 10 days with certain chemicals. Defoliants should also be useful in wet seasons in checking second growth.

Defoliation does not affect the degree of shattering or shelling during the pulling operations, and no differences in threshing efficiency could be noticed. The time required for drying the crop after pulling may be shortened, since the chemical defoliants dry up the leaves and weed growth present.

The first treatment was given much earlier than might be considered normal practice to determine the greatest loss in yield that might occur. In most instances there was considerable reduction in yield and in weight per thousand seeds from this early application. However, with the later application the reductions in seed weight and yields were not so great. Complete coverage of all the foliage on the plants is essential, since leaves that are missed will not drop even though the surrounding foliage falls from the plant. Therefore, the plants are not completely open to sunshine, which will result in delaying the maturity of some of the pods. Chemical defoliants can be applied with the same machinery as that used for weed control in grain crops. With equipment available in most districts, cost of application must therefore be balanced with the gain in quality of the crop and efficiency in handling.

ACKNOWLEDGMENTS

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FUMIGATION OF USED BAGS WITH TOXIC GASES FOR THE CONTROL OF BACTERIAL RING ROT OF POTATO[1]

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ABSTRACT

Ammonia, chlorine, chloropicrin, hydrogen sulphide, methyl bromide, and sulphur dioxide failed to kill the potato ring rot organism (*Corynebacterium sepedonicum*) at dosages of 50, 100, and 150 mgm./l. after 8 and 16 hours of exposure, but ethylene oxide was toxic at 100 mgm./l. after 16 hours and at 150 mgm./l. after 8 and 16 hours. In larger tests with carboxide (10 per cent ethylene oxide and 90 per cent carbon dioxide) and with the contaminated jute squares placed at different levels in 250-bag pressed bales, ethylene oxide was toxic at a dosage of 80 mgm./l. (5 lb./1000 cu. ft.) after 16 and 24 hours of exposure at atmospheric pressure, and after 3 hours under partial vacuum. In a test on a commercial scale and with the contaminated jute squares at different levels in 500-bag pressed bales, it was toxic at the same dosage after an exposure of 24 hours at atmospheric pressure, and 5 and 16 hours under partial vacuum.

INTRODUCTION

Bacterial ring rot of potatoes, caused by *Corynebacterium sepedonicum* (Spiek. and Kott.) Skapt. and Burkh., is still prevalent in many potato-growing areas in Canada. Recommendations for the control of this disease in the past have dealt mainly with the disinfection of potato-handling equipment, and the planting of ring rot free seed potatoes.

In the last few years, the danger of potato ring rot being spread through the medium of contaminated potato bags has become evident. Starr (12), in 1947, published data showing that *C. sepedonicum* remained viable in contaminated potato bags under normal storage conditions for at least seven months. In experiments conducted at Ottawa, as high as 20 per cent ring rot was observed in plants grown from potato sets which had been shaken in a bag contaminated with the ring rot organism seven months previously.

Starr (13) reported excellent control of ring rot bacteria on potato bags by steam sterilization. MacLachlan and Racicot (6) found that a quarternary ammonium compound was an effective disinfectant against the ring rot organism, even at low temperatures, and that potato bags could be disinfected in an infra-red oven. These methods of disinfection are not readily adaptable to commercial practice.

Ethylene oxide first came into prominence as a fumigant in 1928, following the discovery of its insecticidal properties by Cotton and Roark (1). The literature of that period indicates that this discovery may also have been made independently in Germany (15). Subsequently, it was widely used as a fumigant for the control of stored product insects. Velu, Lepigre, and Bellocq (14) discuss the bactericidal properties of ethylene oxide in the gaseous state. Kaye (3) and Phillips and Kaye (10) used ethylene oxide as a fumigant for the sterilization of blankets and other

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hospital equipment, and found that this gas was toxic to many spore-forming bacteria. Kaye and Phillips (4) noted that the action of ethylene oxide in killing the spores of *Bacillus globigii* Migula was about 4 times as rapid at 28 per cent relative humidity as it was at 65 per cent, and 10 times as rapid as at 97 per cent.

Monro (9) showed that methyl bromide was an efficient fumigant for the control of many insects in grain, peanuts, etc., carried in the holds of ships. In his experiments, methyl bromide was found to penetrate downward through solid piles of bags of peanuts for a distance of from 10 to 12 feet. Lear and Mai (5) found that methyl bromide was effective in destroying the cysts of the golden nematode, *Heterodera rostochiensis* Woll., on used potato bags in a pile of 600 tied in bundles of 50.

McCallan and Weedon (8) reported on the toxicity of ammonia, chlorine, hydrogen cyanide, hydrogen sulphide, and sulphur dioxide to *Escherichia coli* (Migula) Cast. and Chalm., a bacterium pathogenic to humans. Salle and Korzonovsky (11) demonstrated the increased effectiveness of treatments under vacuum with germicides in the destruction of bacteria.

In 1949, preliminary tests with toxic gases were begun at Ottawa in the hope that some of these gases would prove lethal to the ring rot organism and might be adapted to fumigation on a commercial scale. The present paper gives the results of fumigation experiments with a number of toxic gases, and of tests on a commercial scale with one of these, namely, ethylene oxide.

MATERIALS AND METHODS

A galvanized-iron fumigation chamber of 10 cu. ft. capacity was used in preliminary trials with the toxic gases. The interior of the chamber was painted with corrosion-resistant paint. Circulation of the air in the chamber was brought about by a small fan which was operated for 10 minutes every hour. The gases were obtained compressed in small cylinders. A needle valve with a rubber tubing connection was threaded to the cylinder from which it was desired to release some of the gas. In each test, the gas was measured and introduced into the chamber by means of a Hempel gas burette. All these fumigations were made at atmospheric pressure.

Small, 2-inch squares of jute burlap were sterilized in an autoclave for 45 minutes at 20 pounds pressure. When cool, they were placed in an aqueous suspension of the ring rot organism for 10 minutes, after which they were placed in sterile Petri plates and allowed to dry at room temperature. It required from 7 to 10 days for the squares to dry.

To help prevent contamination, the fumigation chamber was sprayed with a 10 per cent lysol solution by means of an atomizer. For each test, 10 plates containing treated squares were placed in the chamber. The covers were partially removed from 5 of the plates and left in place on the other 5. The chamber was then closed and the desired volume of gas introduced as mentioned above.

After treatment, the test material was removed from the chamber, and 15 cc. of the ring rot medium described by MacLachlan and Thatcher (7) were poured over each square in the Petri plates that contained them. Five

squares that were not fumigated served as a check, and 15 cc. of the same medium was also poured over them in their respective Petri plates. All these plates were then incubated at 24° C. for 8 days and the presence of *C. sepedonicum* was determined by the microscopic examination of Gram stained smears from colonies that developed on or in the medium.

The toxic gases tested were as follows: Sulphur dioxide, hydrogen sulphide, ammonia, chlorine, chloropicrin, methyl bromide, and ethylene oxide. Dosages of 50, 100, and 150 mgm. per litre (1/20, 1/10, and 3/20 oz. per cu. ft.) were used and the exposure periods were 8 and 16 hours. Because of the poisonous nature of these gases, all the preliminary experiments were conducted under a fume hood.

Large scale tests with ethylene oxide were conducted at the Fumigation Station and Laboratory, Montreal, in a 30-cu. ft. experimental chamber and 1200-cu. ft. commercial fumigation vault. In these large scale tests, the ethylene oxide was applied as carboxide, a mixture of 1 part ethylene oxide and 9 parts carbon dioxide, but all the dosages given are of the active ingredient, ethylene oxide.

In the final tests, the effect of ethylene oxide on two common insects infesting stored products, namely the granary weevil (*Sitophilus granarius* L.) and the cadelle (*Tenebroides mauritanicus* L.), was also determined. The junior author reared the test insects for the experiments and determined the percentage mortality after treatment.

EXPERIMENTAL RESULTS

The results from the preliminary experiments with several toxic gases are recorded in Table 1.

The results recorded in Table 1 indicate that sulphur dioxide, hydrogen sulphide, ammonia, chlorine, chloropicrin, and methyl bromide were ineffective in destroying *C. sepedonicum* on jute squares. Chlorine reduced the numbers of bacteria considerably, but only gave complete sterilization in 2 of the 10 squares treated with the highest dosage and for the longer period. Methyl bromide showed a tendency to stimulate the growth of the organism. Ethylene oxide had a markedly lethal effect. At a dosage of 100 mgm. per litre during a period of 16 hours, it killed the organism in all the 10 squares. It caused complete mortality of the bacteria at a dosage of 150 mgm. per litre and during an exposure of only 8 hours.

As the results obtained with ethylene oxide warranted further study of this fumigant, an experiment was set up in which the volume of the gas could be measured more accurately than in the foregoing experiment and in which the temperature could be controlled. It was carried out at the Fumigation Station and Laboratory, Montreal.

In the several tests, the carboxide was discharged from a 30-pound cylinder into an "accumulator" tank, which was used for storing the fumigant. Immediately before each test, the gas in the accumulator tank was warmed up to 120° F. in order to ensure an even distribution of the two components of the fumigant.

Contaminated jute squares, contained in Petri dishes, were placed in the fumigation chamber, the door was closed, and, by evacuating most of the air from the tank, a vacuum of 20 mm. of mercury was obtained. The required

TABLE 1.—THE EFFECTIVENESS, AT ATMOSPHERIC PRESSURE, OF SEVERAL TOXIC GASES IN KILLING RING ROT BACTERIA ON JUTE SQUARES

Fumigant	Dosage	Exposure	Rel. humidity	Temp. range	Number of squares		
					Treated	B.R.R.+[2]	B.R.R.−[3]
	mgm./1.[1]	hours	%	°F.			
Sulphur dioxide	50	8	43	80–84	10	10	0
	50	16	39	78–82	10	10	0
	100	8	41	83–85	10	9	0
	100	16	45	74–78	10	9	1
	150	8	39	81–84	10	9	1
	150	16	42	76–80	10	10	0
Hydrogen sulphide	50	8	46	78–83	10	10	0
	50	16	43	80–83	10	10	0
	100	8	38	75–78	10	10	0
	100	16	49	70–80	10	10	0
	150	8	47	73–77	10	10	0
	150	16	39	71–78	10	10	0
Ammonia	50	8	45	70–73	10	10	0
	50	16	46	73–78	10	9	0
	100	8	40	69–72	10	10	0
	100	16	38	72–76	10	10	0
	150	8	42	68–72	10	10	0
	150	16	48	70–75	10	10	0
Chlorine	50	8	40	70–73	10	10	0
	50	16	39	69–73	10	9	1
	100	8	46	70–72	10	10	0
	100	16	41	70–74	10	9	1
	150	8	38	69–71	10	10	0
	150	16	43	70–75	10	8	2
Chloropicrin	50	8	37	72–76	10	10	0
	50	16	39	70–77	10	10	0
	100	8	42	72–75	10	10	0
	100	16	40	70–76	10	10	0
	150	8	41	71–74	10	10	0
	150	16	41	70–74	10	9	1
Methyl bromide	50	8	38	70–73	10	10	0
	50	16	42	74–78	10	10	0
	100	8	41	79–72	10	10	0
	100	16	36	65–73	10	9	0
	150	8	39	70–75	10	10	0
	150	16	40	71–76	10	10	0
Ethylene oxide	50	8	42	72–75	10	9	1
	50	16	42	68–74	10	5	5
	100	8	38	71–75	10	5	5
	100	16	40	69–75	10	0	10
	150	8	42	70–74	10	0	10
	150	16	36	68–72	10	0	10
Control	—	—	—	—	—	10	0

[1] Mgm./1. = milligrams per litre.
[2] B.R.R.+ = bacterial ring rot organism living.
[3] B.R.R.− = bacterial ring rot organism killed.

TABLE 2.—THE EFFECTIVENESS, AT ATMOSPHERIC PRESSURE, OF ETHYLENE OXIDE AT DIFFERENT DOSAGES AND FOR DIFFERENT EXPOSURES IN KILLING RING ROT BACTERIA PRESENT ON JUTE SQUARES

Dosage of C_2H_4O	Exposure	Rel. humidity	Temp. range	Number of squares		
				Treated	B.R.R.+[2]	B.R.R.−[3]
mgm./l.[1]	hours	%	° F.			
50	4	46	76–82	10	5	5
50	16	39	75–85	10	0	10
50	64	44	77–81	10	1	9
100	4	41	78–83	10	2	8
100	16	39	76–86	10	0	10
150	4	37	78–85	10	0	10
150	16	46	74–85	10	0	10
Control	—	—	—	—	10	0

[1] Mgm./l. = milligrams per litre.
[2] B.R.R.+ = bacterial ring rot organism living.
[3] B.R.R.− = bacterial ring rot organism killed.

dosage of the gas mixture was calculated from the gas law formula PV = RnT, where P = pressure, V = volume, R = gas constant, n = number of gram-molecules, and T = absolute temperature (2). That quantity was then discharged from the accumulator into the chamber. Following this, air was introduced into the chamber until the pressure reached approximately 730 mm. of mercury. This pressure was slightly less than that of the outside atmosphere and was employed to ensure that there would be no leakage of the toxic gas.

At the end of an exposure period, it was always found that the reading on the vacuum gauge was less than the outside pressure, and consequently there could have been no leakage of the fumigant during the treatment. The fumigant was exhausted from the chamber by "airwashing". This process consisted of drawing two successive vacua to 20 mm. of mercury, and of introducing air to restore the chamber to atmospheric pressure after each vacuum had been drawn.

The gas was tested at dosages of 50, 100, and 150 mgm. per litre, and for exposures of 4 and 16 hours. The results are recorded in Table 2.

The numbers of ring rot bacteria on all squares treated with ethylene oxide were considerably reduced. The organism was not recovered from treatments of 50 mgm. per litre for 16 hours, 100 mgm. per litre for 16 hours, and 150 mgm. per litre for 4 and 16 hours. It was recovered from each of the 10 untreated squares.

A further experiment was conducted with ethylene oxide to compare its effectiveness as a fumigant at atmospheric pressure and under partial vacuum. The procedure for fumigation at atmospheric pressure was similar to that already described. In the treatments under partial vacuum, the pressure in the experimental chamber was not raised, as in the preceding experiment, to atmospheric pressure by the introduction of air, and the time of exposure was 3 hours. The results are recorded in Table 3.

The results given in Table 3 show that at atmospheric pressure, and with a dosage of ethylene oxide of 100 mgm. per litre, an exposure of 16

TABLE 3.—THE EFFECTIVENESS, AT ATMOSPHERIC PRESSURE AND UNDER PARTIAL VACUUM, OF ETHYLENE OXIDE IN KILLING RING ROT BACTERIA ON JUTE SQUARES

Atmospheric pressure or vacuum	Exposure	Dosage of C_2H_4O	Rel. humidity	Temperature	Number of squares		
					Treated	B.R.R.+	B.RR.—
	hours	mgm./l.	%	°F.			
A	16	50	43	75	10	0*	9
A	4	100	38	70	10	2	8
A	16	100	45	74	10	0	10
A	4	150	41	74	10	0	10
A	16	150	40	70	10	0	10
V	3	50	40	72	10	5*	4
V	3	100	39	71	10	0	10
V	3	150	40	74	10	0	10
Control	—	—	—	—	—	9*	0

* One plate was overgrown with fungi.

hours was necessary to kill the ring rot organism. At a higher dosage, namely 150 mgm. per litre, the organism was killed by an exposure as short as 4 hours. In the fumigation under partial vacuum, an exposure to a dosage of 100 to 150 mgm. per litre of ethylene oxide for 3 hours was sufficient to kill the organism.

In order to determine the penetration of ethylene oxide into baled bags, jute squares were placed at the 50-, 100-, 150-, 200-, and 250-bag level in 500-bag bales while the bags were being placed in a press for baling. Six bales were used, and a total of 10 squares were placed in each bale. The bales were placed in the 1200-cubic foot vault on 2 platforms approximately 6 inches from the floor, 3 bales to each platform. The vault door was then closed; a vacuum was drawn; and the contents of two 30-lb. cylinders of carboxide were released into the vault. Air was then let into the chamber until only a slight vacuum existed. The dosage of ethylene oxide was approximately 80 mgm. per litre (5 lb. per 1000 cu. ft.) and the bales were exposed for 24 hours. The results are recorded in Table 4.

TABLE 4.—THE EFFECTIVENESS, AT ATMOSPHERIC PRESSURE, OF ETHYLENE OXIDE IN KILLING RING ROT BACTERIA ON JUTE SQUARES PLACED AT DIFFERENT LEVELS IN 500-BAG BALES

Dosage of C_2H_4O	Exposure	Rel. humidity	Temperature	Position of squares[1]	Number of squares		
					Treated	B.R.R.+	B.R.R.—
mgm./l.	hours	%	°F.				
80	24	48	72	50	12	0	12
80	24	48	72	100	12	0	12
80	24	48	72	150	12	0	12
80	24	48	72	200	12	0	12
80	24	48	72	250	12	0	12
Control	—	—	—	—	—	10	—

[1] Number of bags from surface of bale.

The results from the treatment of 500-bag bales indicate that ethylene oxide is capable of penetrating to the centre of the bales when these are exposed for 24 hours to a dosage of 80 mgm. per litre. No ring rot bacteria were recovered from the treated material, whereas they were recovered from all the untreated squares.

Two jute squares contaminated with *C. sepedonicum* were inserted at the 25-, 50-, 75-, 100- and 125-bag level in six pressed bales of 250 bags each. In addition, two metal capsules, one containing 50 granary weevils and the other 5 cadelles, were inserted in the bales at each of the above-mentioned levels. The bales were then subjected to a dosage of 80 mgm. of ethylene oxide per litre in the 30-cu. ft. experimental chamber. Five of the bales were fumigated at atmospheric pressure, and each for a period of 3, 6, 8, 16 or 24 hours. The sixth bale was fumigated under a partial vacuum of 20 mm. of mercury for 3 hours.

After treatment, the squares and the capsules were removed from the bales, and the number of squares containing viable ring rot bacteria and the percentage of mortality among the insects were ascertained. The results are summarized in Table 5.

The results given in Table 5 show that the treatment with ethylene oxide was completely successful in killing ring rot bacteria only in the 16- and 24-hour exposures at atmospheric pressure. Under partial vacuum, the bacteria still viable at the end of the treatment were on the jute squares placed at the 100- and 125-bag levels. None was viable on the squares placed at the 25-, 50- and 75-bag levels. Unfortunately, during the treatment under partial vacuum, a slight leak developed in the chamber and the vacuum could not be maintained for the full 3 hours. This circumstance rendered the treatment less effective than it would otherwise have been. The granary weevil was completely destroyed by 16- and 24-hour

TABLE 5.—THE EFFECTIVENESS, AT ATMOSPHERIC PRESSURE AND UNDER PARTIAL VACUUM, OF ETHYLENE OXIDE IN KILLING RING ROT BACTERIA AND TWO SPECIES OF INSECTS PLACED AT DIFFERENT LEVELS IN 250-BAG BALES

Atmospheric pressure or vacuum	Exposure	Dosage of C_2H_4O	Temp.	Number of squares			Percentage mortality	
				Treated	B.R.R. +	B.R.R. −	S. granarius[1]	T. mauritanicus[2]
	hours	mgm./l.	°F.					
A	3	80	63	10	8	2	—	
A	6	80	61	10	6	4	100	4
A	8	80	62	10	6	4	10	0
A	16	80	58	10	0	10	100	76
A	24	80	61	10	0	10	100	100
V	3	80	62	10	4	6	72	44
Control	—	—	—	—	10	—	—	—

[1] 250 granary weevils per bale.
[2] 25 cadelles per bale.

fumigations under atmospheric pressure, but the cadelle only by the 24-hour treatment. Under partial vacuum, and for the 3-hour treatment, neither the granary weevil nor the cadelle was completely destroyed.

COMMERCIAL SCALE TREATMENT

In this experiment, the 1200-cu. ft. vault was loaded with 24 pressed bales of 500 bags each. Contaminated squares and test insects were placed in each of 4 bales at the 100-, 200- and 250-bag levels. The bales containing the test materials were placed in the two corners of the vault farthest from the entry point of the fumigant. A dosage of 80 mgm. per litre of ethylene oxide was used, and the exposure periods were 24 hours at atmospheric pressure, and 5 and 16 hours under partial vacuum. In every treatment, the gas mixture was recirculated for 10 minutes every hour from 12 noon to 5 p.m., and, in the treatment at atmospheric pressure, from 8 a.m. to 11 a.m. on the following day. The results are recorded in Table 6.

The results given in Table 6 indicate that the ring rot organism was completely killed when exposed to a dosage of 80 mgm. per litre of ethylene oxide for a period of 24 hours at atmospheric pressure, and for a period of 5 or 16 hours under partial vacuum. Complete mortality in the granary weevil was effected only by the 16-hour treatment under partial vacuum. The cadelle showed a higher level of resistance to the fumigant than did the granary weevil.

TABLE 6.—THE EFFECTIVENESS, AT ATMOSPHERIC PRESSURE AND UNDER PARTIAL VACUUM, OF ETHYLENE OXIDE IN KILLING RING ROT BACTERIA AND TWO SPECIES OF INSECTS PLACED AT DIFFERENT LEVELS IN 500-BAG BALES IN A COMMERCIAL FUMIGATION VAULT

Atmospheric pressure or vacuum	Exposure	Dosage of C_2H_4O	Temp.	Number of squares			Percentage mortality	
				Treated	B.R.R.+	B.R.R.−	S.granarius	T. mauritanicus
	hours	mgm./1.	°F.					
A	24	80	70	120	0	120	99	12
V	16	80	70	120	0	120	100	32
V	5	80	70	120	0	120	69	32
Check	—	—	—	—	19	1	0	0

SUMMARY

1. Under the experimental conditions used in the present study, sulphur dioxide, hydrogen sulphide, ammonia, chlorine, chloropicrin, and methyl bromide were not effective in killing the ring rot organism.

2. Ethylene oxide at a dosage of 80 mgm. per litre (5 lb. per 1000 cu. ft.), and during a period of 24 hours at atmospheric pressure, and of 5 hours under partial vacuum, caused complete mortality of the ring rot organism in 500-bag bales.

3. Although ethylene oxide has been shown to be effective against stored product insects, under the conditions of the present experiments, the penetration of the fumigant in sufficient concentrations to be completely toxic to the test insects was not obtained throughout the pressed bales containing 500 bags. At a dosage of 80 mgm. per litre in a 30-cu. ft. chamber at atmospheric pressure, it completely killed the granary weevil in 250-bag bales in 16 hours and the cadelle in 24 hours. In a 1200-cu. ft. chamber at atmospheric pressure for 24 hours, using 500-bag bales, mortality among the former was 99 per cent and, under partial vacuum for 16 hours, 100 per cent; but, under neither conditions, was mortality among the latter complete.

ACKNOWLEDGMENTS

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ADSORBED PHOSPHORUS IN HIGH-LIME ONTARIO SOILS[1]

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ABSTRACT

A series of ten high-lime Ontario soils was examined for total adsorbed, and total acid-soluble phosphorus by the laboratory methods of Bray and Kurtz. Five-tenths normal ammonium fluoride was used for the former, and one-tenth normal hydrochloric acid for the latter.

Five of the samples were alkaline, and the remaining five non-alkaline (neutral to slightly acid). The former group was found to exhibit a range of adsorbed phosphorus values, the higher of which exceeded any found in the latter group.

A study of phosphorus retention from solution indicated that with a 50-p.p.m. addition, 90 and 98 per cent was retained by a high and a low phosphorus soil respectively. Likewise with a 500-p.p.m. addition, 52 and 72 per cent was retained by the same soils.

Extraction of the treated soils by the fluoride method used above resulted in 62.2 and 89.8 per cent recovery, respectively, of the 50-p.p.m. addition, and 89.2 and 79.5 per cent recovery, respectively, of the 500-p.p.m. addition. The low phosphorus soil appeared to yield up a larger proportion of the retained phosphorus at the lower rate of addition, but this difference was not apparent at the higher rate.

As a result of this study, it is felt that significant levels of adsorbed phosphorus can be present, even in high-lime soils. Previous studies indicating the importance of adsorbed forms of phosphorus in plant growth, together with observations on response to phosphorus in relation to the values reported here, suggest the desirability of including such forms in assessing the phosphorus fertility status of these soils.

Difficulties encountered in assessing available phosphorus levels in high-lime Ontario soils constitute an important problem in predicting phosphorus fertilizer requirements. According to reports of the Ontario Soil Survey (6, 10, 11), soils in high-lime areas frequently respond to light applications of phosphorus fertilizer. Such applications are usually drilled with the seed of oats, wheat, and corn at planting-time. Although heavy phosphorus applications have given further responses with crops grown in the greenhouse, there is little data to indicate similar responses under field conditions. Yet the five-hundredths normal hydrochloric acid extracting solution used in a narrow soil-solution ratio for testing these soils indicates many samples to be very low in acid-soluble phosphorus and thus they might be considered highly responsive. On the other hand, the potassium acid sulphate solution of Lohse and Ruhnke (8), buffered at pH 2.0 and used in a wide soil-solution ratio, extracts large amounts of phosphorus which might suggest adequate amounts for normal growth. The authors of this method state, however, that it possesses limited value in assessing the phosphorus fertility status of high-lime soil materials. McGeorge *et al.* (9) have made exhaustive studies on phosphorus availability in the calcareous soils of Arizona. They favour the use of carbon dioxide bubbled through a soil-water suspension as an extractant for available phosphorus. This method gives very low values for most of the Ontario soils which have been tested.

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While the chemical forms of phosphorus prevalent in high-lime soils have been studied rather extensively, much of the stress in correlating soil test results with crop growth has been based on the extraction of the calcium forms of phosphorus by various acid extractants. More recently, adsorbed or exchangeable forms of soil phosphorus have been studied (2, 5, 7) and postulated as contributing materially to the phosphorus nutrition of crops. Such forms have been found to correlate satisfactorily with response to phosphorus fertilization (4). While adsorbed forms of phosphorus would not be expected to constitute a large proportion of the total in high-lime soils, the extent of their presence should be a matter of special interest.

It appears feasible that such forms could be considered along with the forms presently measured to improve soil test correlations with crop response. The present investigation deals with amounts and behaviour of adsorbed forms of phosphorus in a group of Ontario soils.

MATERIALS AND METHODS

The soils used are for the most part representative of the Grey-Brown Podzolic great soil group. They have developed on high-lime parent materials, mainly under forest cover. The total phosphorus content of the parent material is relatively high, occurring mainly in apatite from which it must be released before it can be readily used by plants. A more detailed description of the soils of the region appear in Reports No. 7, 9, and 11 of the Ontario Soil Survey (6, 10, 11).

Ten soil samples obtained from the cultivated layer of farm fields were chosen to represent a range in reaction and phosphorus response. While detailed evidence of response was not available, three soils were considered

TABLE 1.—SOURCE, REACTION, AND PHOSPHORUS RESPONSE OF TEN ONTARIO SOILS

Soil No.	County	Township	Conc.	Lot	Reaction	Phosphorus Response
1	Peterborough	N. Monaghan	XII	3	7.7	Nil
5	Ontario	Scott	III	3	7.4	Nil
6	York	Vaughan	II	21	7.4	Nil
7	Durham	Clarke	II	34	6.8	Moderate*
10	Ontario	Brock	XIII	16	7.6	Moderate*
12	Ontario	Pickering	III	30	7.8	Full**
14	Lincoln	Caistor	II	7	5.2	Full**
16	Carleton	Osgoode	V	41	6.7	Moderate*
18	Durham	Darlington	VI	15	7.1	Full**
20	Essex	Maidstone	C.R.	18	6.4	Full**

* "Moderate" refers to response to light applications of phosphorus with or near the seed only.
** "Full" refers to further response to heavier soil applications of phosphorus in addition to the seed treatment.

to respond to light applications of phosphorus fertilizer with or near the seed (moderate response), four to heavier applications in addition to the seed treatment (full response), and the remaining three were not considered to respond to phosphorus fertilization. Table 1 gives the source, reaction, and response to applied phosphorus of the ten soils.

Total adsorbed and total adsorbed plus acid-soluble phosphorus combined was determined by laboratory methods of Bray and Kurtz (3), in which five-tenths normal ammonium fluoride was used in a one-hour extraction for the adsorbed or replaceable phosphorus. The combined fraction was extracted by a one-hour shaking with one-tenth normal hydrochloric acid followed by an additional 30-minute shaking with fluoride. The acid-soluble fraction alone was calculated by subtraction of the previously determined adsorbed fractions. A one to fifty soil-solution ratio was used throughout. Soil samples were ammonium-saturated before extraction.

In addition, samples 1 and 12 were selected, because of their difference in level of total adsorbed phosphorus, to study the ability of these soils to retain and release added phosphorus. With each soil, three separate two-gram samples were shaken for 5 hours in 17-ml. centrifuge tubes with 10-ml. portions of solution containing respectively 0, 10 and 100 p.p.m. phosphorus as potassium dihydrogen phosphate. Following the shaking, the tubes were allowed to stand an additional 19–20 hours, again shaken to mix the contents, and centrifuged at 3000 r.p.m. Aliquots of the clear supernatant liquid were removed for determination of the phosphorus remaining in solution. Phosphorus retained by the soil was calculated on the soil basis.

Following the retention of phosphorus, the amount of retained phosphorus which could be recovered from the two treated samples was determined. Samples were first leached with water, then with ammonium chloride, and finally extracted by the previously described methods for total adsorbed and acid-soluble phosphorus.

TABLE 2.—REACTION, FREE CARBONATE, AND PHOSPHORUS VALUES FOR TEN ONTARIO SOILS

Soil	Reaction	Free carbonates	Total adsorbed P	Total acid-soluble P
	pH		p.p.m.	p.p.m.
Alkaline				
1	7.7	Abundant	75	500
5	7.4	Very slight	85	435
6	7.4	Slight	135	515
10	7.6	Very slight	72	428
12	7.8	Slight	17	293
Non-alkaline				
7	6.8	None	50	430
14	5.2	None	25	90
16	6.7	None	40	620
18	7.1	None	40	120
20	6.4	None	28	172

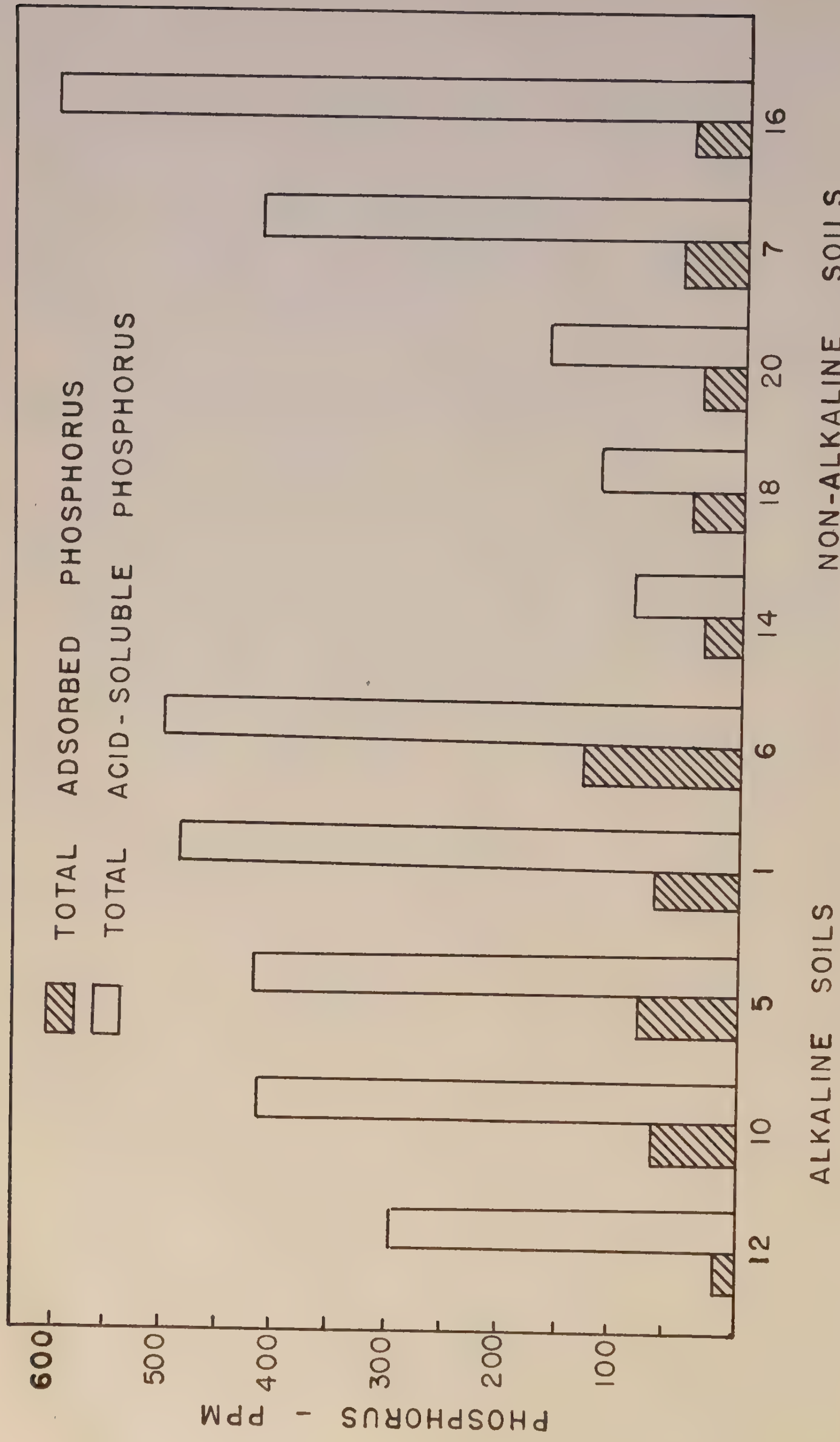

Figure 1. Relationship between total adsorbed and total acid-soluble phosphorus in ten Ontario soils.

EXPERIMENTAL RESULTS

The results of the phosphorus determinations are given in Table 2. The ten soils have been divided into two groups, based on reaction and the presence of free carbonates. It is evident that the sum of the two fractions are higher in the alkaline group than in the non-alkaline group. The tenth-normal hydrochloric acid extraction has removed several times as much phosphorus as has the five-tenths normal fluoride. The proportion of acid-soluble to adsorbed phosphorus tends to be similar in each group. Figure 1 illustrates graphically the relationship between the two forms of phosphorus.

The results of the phosphorus retention study appear in Table 3 and the amounts of phosphorus recovered from the treated soils are given in Table 4. A lower percentage of added phosphorus has been retained by the soil exhibiting the higher level of phosphorus (No. 1), and a larger amount of phosphorus has been retained in the case of each soil when higher additions are used. Approximately 80 per cent of the 360 p.p.m. initially retained by the low phosphorus soil (No. 2) and 90 per cent of the 260 p.p.m. retained by the high phosphorus soils has been recovered up to and including the fluoride extraction. With the 50 p.p.m. additions the high phosphorus soil has retained a larger portion in forms which are not extracted by fluoride than has the low phosphorus soil.

TABLE 3.—PHOSPHORUS RETENTION STUDIES ON TWO ALKALINE ONTARIO SOILS

Soil No.		1			12	
pH		7.7	(Carbonates slight)		7.8	(Carbonates abundant)
Total adsorbed P.—p.p.m.		75			17	
Total acid-soluble P.—p.p.m.		500			293	
P added—p.p.m.						
—sol'n basis	0	10	100	0	10	100
—soil basis	0	50	500	0	50	500
P retained—p.p.m.						
—soil basis	−2	45	260	−2	49	360
—per cent	—	90	52	—	98	72

TABLE 4.—RECOVERY OF RETAINED PHOSPHORUS

Soil No.	1			12		
P originally added—p.p.m.	0	50	500	0	50	500
P recovered—p.p.m.						
(*a*) water	3	5.5	40	1	2	45
(*b*) NH_4Cl leach	15	24.5	100	5	10	105
(*c*) 0.5N NH_4F	94	110	205	22	60	165
Total	112	140	345	28	72	315
Net recovery*—p.p.m.	—	28	233	—	44	287
Originally adsorbed—p.p.m.	—	45	260	—	49	360
Per cent recovery	—	62.2	89.2	—	89.8	79.5
Acid-soluble P—p.p.m.	515	—	540	293	—	360
Acid-soluble recovery* —p.p.m.	—	—	25	—	—	67
Total per cent recovery	—	—	99.2	—	—	98.3

* Recoveries are arrived at by subtracting the values for the untreated soils from the corresponding value for the treated soil.

DISCUSSION AND CONCLUSIONS

The tendency of certain high-lime soils to give little or no crop response to applied phosphorus fertilizer suggests that an adequate supply of available soil phosphorus occurs naturally or has been built up through management. It is to be expected that calcium forms of phosphorus will be dominant in such soils, yet calcium forms, particularly di- and tricalcium phosphate, are considered to possess limited availability to crops. The presence of the relatively more available adsorbed forms, as indicated in this study, might account in part for the favourable phosphorus feeding exhibited by these soils.

The accumulation of adsorbed forms of phosphorus in high-lime soils is largely a matter of speculation. It might be explained to result from successive cycles of organic matter formation and decay, wherein small amounts of phosphorus are taken up from relatively unavailable mineral forms, and redeposited in more available forms. The behaviour of soluble phosphorus additions, as reported here, suggests that a part of the unused, soluble portion of applied fertilizer is retained as an adsorbed form. This suggests that the phosphorus fixation problem in soil management may not be too serious.

While adsorbed forms of phosphorus may not be as important as the calcium forms, their presence could be expected to add materially to the supply of soil phosphorus available for crop growth. Comparison of observed phosphorus response in the field with the range of phosphorus levels reported here suggest that such forms may be of significance for crop growth on high-lime soils.

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THE CONTROL OF VERTICILLIUM WILT OF POTATOES BY SEED TREATMENT[1]

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ABSTRACT

Evidence is presented that seed treatment with the organic mercury fungicide Semesan Bel gives good control of potato wilt caused by *Verticillium albo-atrum* R. & B.

INTRODUCTION

The potato wilt disease that is caused by the fungus *Verticillium albo-atrum* R. & B. is one of the more serious causes of loss to potato growers in some of the seed producing areas of North America. Ayers and Hurst (1) reported that, in Prince Edward Island, the yield in infected fields may be reduced by as much as one-third, and seed inspection records for that province for the years 1947 to 1951 show that a total of over 1000 acres were refused certification because of the presence of the disease. Folsom, Wyman and Westin (2) state that in Maine there has been an increase in the occurrence of wilt in recent years, and Neilsen (3) in Idaho reports it as being the cause of premature death of vines.

Pethybridge, as reported by Rudolph (4), was able to control the disease, without injury to the plants, by heating the tubers for 20 hours at 44.5° C. Antibiotics also have been developed that effectively inhibit the growth of *Verticillium* spp. in culture (5, 6), but there are no reports of a successful and practical means of controlling Verticillium wilt by chemical treatment of the seed potatoes.

The purpose of this paper is to record the results that have been obtained from the treatment of potato sets and tubers for the control of the disease.

MATERIALS AND METHODS

The variety Irish Cobbler, known to be highly susceptible to wilt, was used throughout the tests. Infected seed tubers were obtained from growers who had suffered considerable loss from wilt in the previous year, but whose crop was relatively free from other diseases. The healthy seed used for control plantings was obtained from growers whose potatoes were certified to be almost completely free from any disease. All tests were carried out on land believed to be free from contamination by the wilt organism.

The organic mercurial Semesan Bel was selected for use as a seed treatment. Its active ingredients are hydroxymercurinitrophenol (12 per cent) and hydroxymercurichlorophenol (2 per cent). Treatment was carried out as an instant dip of seed tubers in a solution as recommended by the manufacturer.

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As the initial symptoms of the disease usually appear in early August and increase in intensity until the end of the season, the counts of wilted plants recorded in the tests were made as late in the season as possible, but before drought or senescence masked the characteristic symptoms of the disease.

EXPERIMENTAL PROCEDURES AND RESULTS

A preliminary trial, to determine whether or not a seed treatment might be of any value, was carried out by planting two blocks each with 1536 seed pieces from tubers harvested from an infected crop. The seed pieces planted in one block were treated after cutting, those in the second block were planted without treatment. These blocks developed 12.5 and 58.9 per cent wilted plants respectively, a result indicating that the treatment appreciably reduced the incidence of the disease. Experiments were undertaken in the two years following to determine whether the results of the preliminary trial could be confirmed.

In the first experiment, the healthy and the Verticillium-contaminated seed were each divided into three lots. For each type of seed, Lot I was treated whole, Lot II was cut into sets and then treated, and Lot III was left untreated as a control. All lots were cut into seed pieces before planting and the treatments were set out in a randomized block design, with four replicates. Each plot contained 100 seed pieces. The second experiment was similar to the first, except that the treatment of cut sets was omitted and each plot contained 55 seed pieces.

The percentage of wilt and the yield of tubers for the various treatments of these tests are given in Table 1.

TABLE 1.—THE EFFECT OF SEED TREATMENT WITH SEMESAN BEL ON THE OCCURRENCE OF VERTICILLIUM WILT AND ON THE YIELD OF TUBERS

Type of seed and treatment used	Percentage wilt	Yield in bu./acre
Experiment I		
From wilt infected plants untreated	59.1	130.5*
From wilt infected plants treated whole	31.0	179.2
From wilt infected plants treated cut	29.7	173.9
From healthy plants untreated	5.7	220.8
From healthy plants treated whole	1.3	248.1
From healthy plants treated cut	0.9	221.6
D.R.S. at P = 0.05		42.5
Experiment II		
From wilt infected plants untreated	51.0	125.5*
From wilt infected plants treated whole	7.7	166.7
From healthy plants untreated	1.2	181.0
From healthy plants treated whole	0.2	184.0
D.R.S. at P = 0.05		41.2

* Significantly less than other yields in the respective experiment.

The results given in Table 1 show a marked reduction in wilt development and a statistically significant increase in tuber yield when infected seed stock was treated with a disinfecting agent before planting. The effectiveness of the treatment is further evident from the fact that the yield obtained from healthy tubers did not differ statistically from that obtained from treated wilt-tubers, whereas it was significantly greater than the yield obtained from untreated wilt-tubers. The data of Experiment I also show that no appreciable differences in results were obtained from treating the cut seed pieces rather than the whole tubers.

A further two-year experiment was performed to obtain information on the rate at which the disease, when unchecked, may progress through a grower's potato stock, and to show what concomitant control may be expected from seed treatment. In 1948 a sample of tubers, obtained from a field that showed 20 per cent wilted plants late in the 1947 season, was divided into two equal parts. One lot was treated and the other left untreated. Similarly treated lots of seed certified as wilt-free were also included. The various lots were cut into seed pieces and planted in a randomized block design, with four replicates. Each plot consisted of 250 seed pieces. Records on disease incidence were taken in midsummer by counting the numbers of wilted plants, and the yield of tubers given by each treatment was obtained by fall harvesting of plots. At the time of harvesting a representative sample of tubers from the untreated, wilt-infected plots was saved, and this sample was used as the diseased seed in setting out the test in the succeeding year. In this second year fresh seed, certified as wilt-free, was obtained and used as the healthy stock. Similar treatments and plot design were used except that each plot in 1949 contained 400 seed pieces. A nearly perfect stand of plants was obtained in both years of the test, and so no account was taken of misses in the recording of results.

The wilt development and yield of tubers for the various treatments of these tests are given in Table 2.

TABLE 2.—THE PROGRESSIVE INCREASE OF VERTICILLIUM WILT IN INFECTED LOTS OF POTATOES AND THE CONTROL OBTAINED BY SEED TREATMENT

Type of seed and treatment used	Percentage of plants wilted[1]		Yield of tubers	
	1948	1949	1948	1949
			lb.	bu./acre
From wilt infected plants untreated	(20.0) 51.5	(51.5) 79.9	482.5*	355.6*
From wilt infected plants treated	(20.0) 7.4	(51.5) 40.2	638.0	496.3
From healthy plants untreated	(Trace) 0.5	(Trace) 24.8	652.9	496.1
From healthy plants treated	(Trace) 0.2	(Trace) 1.7	621.5	546.1
	D.R.S. at P = 0.05		113.0	55.4

[1] Figures in brackets are the percentages of plants wilted in the crop that produced the seed used in the experiment.
* Significantly lower than other yields of the year.

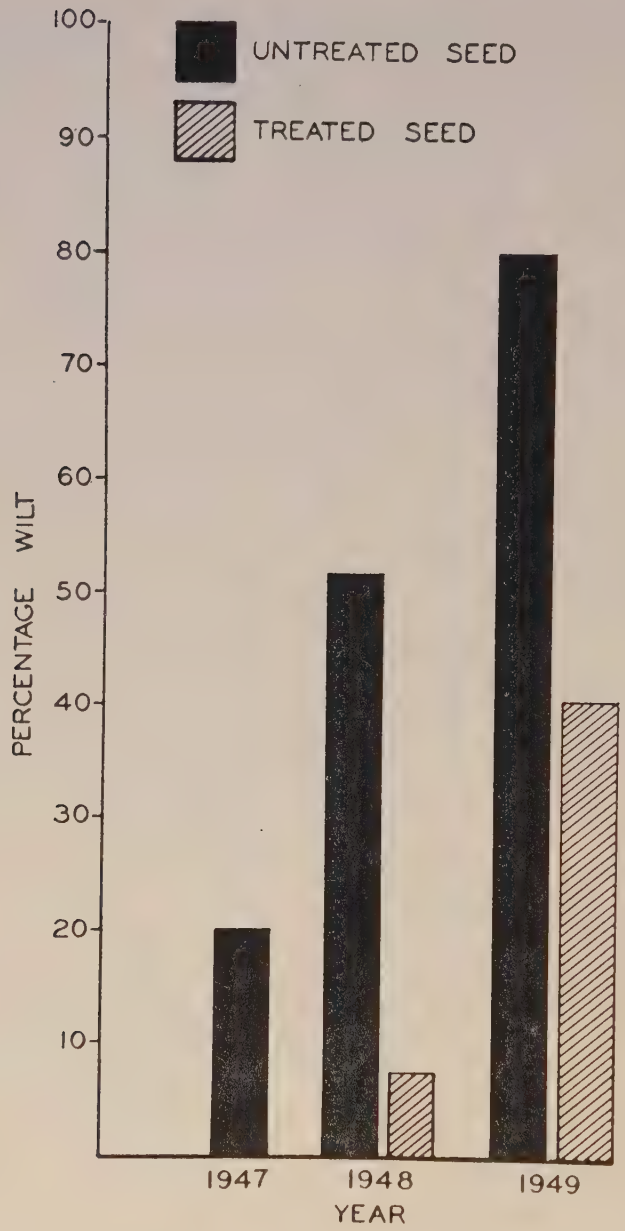

FIGURE 1. The progressive increase in wilt in an untreated stock, and the concomitant control given by seed treatment in each year.

The results given in Table 2 show that in the plots planted with untreated infected seed, the incidence of wilted plants increased 31.5 per cent (from 20.0 per cent to 51.5 per cent) in 1948, and 28.4 per cent (from 51.5 per cent to 79.9 per cent) in 1949. Compared with this, in the plots planted with treated infected seed, the incidence of wilted plants was reduced 44.1 per cent (from 51.5 per cent to 7.4 per cent) in 1948, and 39.7 per cent (from 79.9 per cent to 40.2 per cent) in 1949. These results are illustrated in Figure 1. In both years of the test the marked decrease given by seed treatment in the incidence of wilted plants was accompanied by a corresponding significant increase in the yield of tubers. The healthy seed used as wilt-free checks showed no such increase in yield from seed treatment, and this fact is evidence that the reduction of wilt in the treated infected series is directly responsible for the increased yield of tubers. Contrary to expectations, the fresh healthy seed obtained in 1949, and certified as wilt-free, developed 24.8 per cent wilted plants, but the value of seed treatment is again clearly shown by the reduction of this to 1.7 per cent in the treated lots.

The tubers harvested from the 1949 experiment were divided into "large" and "small" lots with an upper weight limit in the small category of approximately three ounces. From a comparison of the yields in the two lots it was possible to determine whether the presence of the disease resulted in lower yields because of the development of fewer tubers or because the tubers were smaller. The yields obtained in the two lots are given in Table 3.

TABLE 3.—THE EFFECT OF VERTICILLIUM WILT ON THE YIELD OF LARGE AND SMALL TUBERS

Type of seed and treatment used	Class	Yield in bushels per acre	
		Large tubers	Small tubers
Diseased untreated	I	289.5*	66.1
Diseased treated	I	441.9	54.4*
Certified untreated	II	431.8*	64.3
Certified treated	II	496.4	49.7*
D.R.S. at P = 0.05		54.1	5.7

* Significantly lower than the corresponding yield in the respective class.

The data on yield of large tubers show the same beneficial effect from seed treatment as that recorded in Table 2, but with added emphasis because a significant increase in yield is now apparent in the certified treated seed over the certified untreated, whereas no such difference could be demonstrated in the total yield shown in Table 2. The data on yield of small tubers, however, show an opposite result. The yield of small tubers was increased in the absence of treatment and where the disease was not controlled. The logical explanation for these facts is that a proportionately larger number of small tubers was developed by the wilted plants, and it appears, therefore, that Verticillium wilt reduces the yield of potatoes by preventing the tubers from attaining their normal size rather than by reducing the number of tubers formed.

DISCUSSION

The data presented show that the treatment of either whole or cut seed is very effective in reducing the incidence of wilt in stands of Irish Cobbler potatoes. Marked reduction of the disease by such seed treatment, as shown by increased tuber yields and reduced foliar symptoms, was obtained in four separate tests. The results are at variance with what might be expected in view of the etiology of the disease, as the fungus is known to inhabit the vascular system of the plant and to produce a true hadromycosis. The degree of control obtained by surface sterilization methods, however, is satisfactorily explained by assuming that most of the infection arises, not from mycelia within seed tubers, but from conidia or mycelia borne externally on them. The great abundance of such surface inoculum has been reported in a previous paper (1). This assumption is supported by the sudden appearance of wilt in seed stocks hitherto known to be almost free from the disease, and the almost complete control that can be effected by seed treatment of such stocks. The reduction of wilt from 24.8 to 1.7 per cent that was obtained in a supposedly wilt-free stock, as shown in Table 2, is an instance of this. The view that surface borne inoculum is largely responsible for disease development affords the most ready explanation for the results shown in Figure 1. As the potato stock became progressively infested with wilt, the proportionate control afforded by surface treatment became less, a result that would be expected if the fungus were gradually establishing itself within the tubers and so augmenting a source of infection not accessible to the action of a fungicide.

SUMMARY

1. Treatment of infected seed with an organic mercury fungicide (Semesan Bel) is an effective means of substantially reducing the incidence of wilt caused by *Verticillium albo-atrum* R. & B.

2. Treatment is equally effective on whole or cut seed.

3. Reduction in wilt is accompanied by increases in the yield. These increases are apparently due to larger size, rather than greater number, of the tubers formed.

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FURTHER OBSERVATIONS AND INVESTIGATIONS ON MANGANESE DEFICIENCY IN FRUIT TREES IN BRITISH COLUMBIA[1]

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ABSTRACT

A manganese deficiency has been found on many species of plants in the southern interior of British Columbia. In most instances the deficiency is slight and the symptoms are somewhat similar, viz., a yellowing of the tissues in the interveinal and marginal areas of the leaves. In a few areas marked deficiency symptoms have been found and they are characterized by poor leaf development and necrosis of some tissues. The results of chemical analysis indicated a good correlation between the presence of manganese deficiency symptoms and the manganese content of affected tissues. Compatibility studies have shown that Tecmangam (67 per cent manganous sulphate), D.D.T., and Parathion may safely be used together.

In the summer of 1950, it was shown (1) that a moderate manganese deficiency occurred on peach, apple, and apricot in a small localized area in the Okanagan Valley in British Columbia. The experimental work reported covered the results of investigations in one year and the symptoms described were those observed in the area under study. In the present paper the authors describe additional symptoms associated with this deficiency, report a widespread occurrence of the deficiency on many kinds of plants in the Okanagan and adjacent valleys, and present the results of further analyses and control experiments.

ADDITIONAL SYMPTOMS

It was observed that the characteristic colour pattern in the leaves as already described (1), does not normally develop until the youngest leaves have reached their full size. Moreover, leaves on spurs develop symptoms earlier than those on the terminal growth and, on the latter, the older leaves are affected first (Figure 1). Where the deficiency is more severe, the colour pattern tends to disappear and all of the leaves become completely chlorotic. The attachment of the leaf petioles to the branch is weakened and heavy defoliation may be induced either by a strong wind or by the application of a spray. In addition, some of the leaves are much smaller in size (Figure 2), terminal growth is weak, some die-back may occur (Figure 3), and the crop is reduced in size and quality. Under these extreme conditions, it is difficult to distinguish between manganese deficiency and lime-induced chlorosis on peach. No diagnostic symptoms have been observed on the fruit from affected trees.

The syndrome is the same in leaves from many plants when the deficiency is moderate (Figure 4), but when the deficiency is severe some additional symptoms have been observed on certain plants. On peach, a spot necrosis in the leaves occurs which develops almost immediately into a shot-hole condition. The holes are very numerous and small, about 2 mm.

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diam. (Figure 5). The leaves of Chinese chestnut, especially those on the terminal growth, roll upwards and inwards and become severely scorched (Figure 6).

The symptoms on pear are difficult to recognize as the fading of the colour between the veins is much less marked than on other species observed. The severity of the symptoms or of requirement may vary within the horticultural varieties of a species. It has been noticed, for example in apple varieties, that the leaves on McIntosh and Newtown trees may have pronounced symptoms while those on Delicious trees, planted alternately with them, show no symptoms whatever.

AREA AND KINDS OF PLANTS AFFECTED

During the summer of 1951 a survey was conducted throughout the Okanagan Valley. Typical symptoms of deficiency were found in most districts and these occurred on several kinds of plants in addition to those (peach, apple, and apricot) previously reported (1). The plants on which symptoms were recognized for the first time were plum, prune, cherry, pear,

TABLE 1.—THE MANGANESE CONTENT OF LEAVES OF PLANTS FROM DIFFERENT PARTS OF THE OKANAGAN VALLEY (P.P.M. ON A DRY WEIGHT BASIS)

District	Kind of Plant	Variety	Manganese Content	
			Diseased	Healthy[1]
Keremeos	Apple	Newtown	17 – 23	48 – 150
	Peach		13	24 – 51
Penticton	Apple	Newtown	13	
	Peach		20	
Summerland	Apple	McIntosh	9 – 12	54 – 145
		Delicious	16*	50 – 160
	Peach		11	
	Prune	Italian	8 – 12	108 – 157
	Cherry	Bing	13 – 20	72 – 268
	Raspberry		10 – 38	104 – 161
	Grape		22	
Westbank	Peach		9	
	Pear	Bartlett	6 – 10	53 – 147
	Filbert		11 – 15	39
	Chestnut	European	34	48
		Chinese	11 – 16	74
	Heartnut		18 – 26	121
	Walnut	Broadview		86 – 92
Kelowna	Apple	Newtown	26	
		McIntosh	32	
Vernon	Apple	Delicious	8	
	Plum		22 – 24	
North Kamloops	Cherry	Van	15	
		Star	17	

[1] Most of the healthy samples were collected in the Summerland district.

* Symptoms of manganese deficiency were not present but McIntosh trees on either side had marked symptoms of the deficiency.

FIGURE 1. Manganese deficiency on Chinese chestnut. The symptoms, interveinal chlorosis, are quite apparent on the lower or older leaves but absent on the upper or younger ones.

FIGURE 2. Manganese deficiency on peach leaves showing a decreasing degree of severity from (*a*) to (*g*). Note the very small leaf when the deficiency is acute.

Figure 3 Manganese deficiency on peach. Note the sparse foliage and dieback on some of the branches

FIGURE 4. Manganese deficiency on apricot, peach, and apple. Note the similarity of the pattern caused by the interveinal chlorosis in the lower leaves. The upper leaves are from healthy trees.

grape, raspberry, walnut, filbert, Chinese chestnut, European chestnut, heartnut, tulip tree, cottonwood, and spinach. The districts in which affected plants were found were Keremeos, Penticton, Naramata, Summerland, Westbank, Fintry, Kelowna, Vernon, and North Kamloops. Samples for analysis were collected from most kinds of affected plants and the results of the analyses are presented in Table I. There are also included in this table, for purposes of comparison, the results of analyses of comparable tissues from healthy plants. These latter were collected mostly in the Summerland district.

These observations and analyses establish the widespread occurrence of a manganese deficiency on many kinds of plants in the Okanagan and adjacent valleys in British Columbia.

CONTROL EXPERIMENTS AND RESULTS

Control experiments similar to those previously reported (1) were continued. Manganous sulphate (Tecmangam, 67 per cent manganous sulphate) sprays, in varying strength and number, combined and not combined with insecticides, were applied to peach, apple, and apricot trees at different stages of seasonal development in nine separate plots. The effectiveness of the treatments was determined by observations on tree condition and by chemical analyses of leaves from the experimental trees. The pH of the soil in several of the plots was measured. Observations and analyses of leaf tissues were also made on peach trees used in the 1950 control experiment. Manganese was determined by the periodate method.

Plot No. 1

Eleven 10-year-old Elberta peach trees, which had shown symptoms of a moderate deficiency in 1950, were sprayed on April 4, i.e. in the dormant stage, with a combined spray mixture of Tecmangam and ferbam. The materials were applied with a concentrate sprayer which delivered the manganese compound at 5 pounds per acre and the ferbam at 10 pounds per acre. The treatment was not effective. Symptoms appeared on the sprayed trees at the same time and to the same degree of severity as on the checks. In October leaves for analyses were collected and the results, as shown in Table 2, indicate no significant difference in the manganese content of leaves from treated and untreated trees.

TABLE 2.—THE MANGANESE CONTENT OF PEACH LEAVES (P.P.M. ON A DRY WEIGHT BASIS)

Treatment	No. of Samples	Leaf Condition	Manganese Content		
			Low	High	Average
Sprayed 1950, 1 lb. $MnSO_4$	8	Chlorotic	10	18	13
Dormant spray, 1951 (Plot 1)	4	Chlorotic	13	15	14
Untreated	4	Chlorotic	14	16	15
Sprayed June 28, 1 lb. $MnSO_4$ (Plot 4)	2	Green	81	153	117
Sprayed July 12, 2 lb. $MnSO_4$ (Plot 5)	4	Green	152	252	216
Untreated	10	Green	24	108	48

Plot No. 2

Four mature peach trees with severe symptoms were sprayed on June 30 with a solution of 1 pound Tecmangam in 100 gal. of water. In one week's time the leaves showed signs of partial recovery. On some leaves small green spots appeared; on others the margins became green; and on still others these conditions were found together. On July 9, a second spray was applied, using 2 pounds of the same material in 100 gal. water. By the end of August all leaves were again a normal green.

Plot No. 3

Ten mature peach trees with moderate to severe symptoms, were sprayed on July 10 with a concentrate sprayer delivering 5 pounds Tecmangam per acre. In less than one month, leaves which had severe symptoms had partially recovered while those with moderate symptoms were again normal. The trees remained in this condition for the balance of the season.

Plot No. 4

Twenty mature peach trees with moderate to severe symptoms were sprayed on June 28 with a solution of 1 pound Tecmangam in 100 gal. of water. On July 6, eight of these and on August 9 another four received a second application with the same strength spray solution. The recovery response paralleled very closely that recorded in Plot No. 2, where two sprays were applied. However, by the end of the season the recovery on the entire plot appeared to be about the same. In this case the single application, which four trees received, effected a complete recovery of leaf colour. This result varies from that observed in Plot No. 3, where severely affected leaves made only à partial recovery after a single treatment. The manganese content of the leaves on trees which received one treatment only on June 28 is presented in Table 2.

Plot No. 5

Eight mature peach trees with moderate to severe symptoms were sprayed on July 12 with a solution of 2 pounds Tecmangam in 100 gal. of water. Four of these received a second application of the same strength solution on August 7. Tree response was similar to that observed on Plot No. 4. The second application definitely accelerated the rate of recovery but by the end of the season the leaves on all trees were again normal in colour. The manganese content of leaves from the four trees receiving only the one treatment is presented in Table 2.

Plot No. 6

Four 25-year-old Newtown apple trees were sprayed at the time of the first cover spray (June 7) with a solution of 1 pound Tecmangam in 100 gal. of water. At the time of application the leaves indicated the presence of a moderate manganese deficiency, i.e. the symptoms were confined to the characteristic colour pattern in the leaves. By June 22 the light green areas had disappeared and the leaves continued normal in appearance for the remainder of the season.

FIGURE 5. Severe manganese deficiency on peach showing shot hole condition.

FIGURE 6. Manganese deficiency on Chinese chestnut showing various degrees of severity from slight to severe. Note the curled and twisted leaves on the branch that is most severely affected.

Plot No. 7

Three mature McIntosh apple trees, showing a manganese deficiency of moderate degree, were sprayed on June 21 with a combined spray mixture of Tecmangam, 1 pound; D.D.T., 1½ pounds; and Parathion, 1 pound; in 100 gal. of water. The results indicated a compatibility between these materials, for the deficiency was corrected, the insects were controlled and no foliage injury developed.

Plot No. 8

Fifteen mature apricot trees with moderate manganese deficiency symptoms were used in an experiment to determine the effectiveness of weak solutions of manganese sulphate. Eight trees were sprayed the first week of July with a solution of a half pound Tecmangam in 100 gal. of water and the remaining seven with a solution containing half as much of this material. Both solutions effected a complete recovery by the second week in August. In October, leaves for analyses were collected from trees receiving each treatment and from untreated checks. The results are presented in Table No. 3.

TABLE 3.—THE MANGANESE CONTENT OF APRICOT LEAVES (P.P.M. ON A DRY WEIGHT BASIS)

Treatment	No. of Samples	Leaf Condition	Manganese Content		
			Low	High	Average
None, orchard No. 1	4	Chlorotic	8	11	10
None, orchard No. 2	4	Chlorotic	10	12	12
Sprayed, ½ lb. $MnSO_4$	4	Green	41	78	61
Sprayed, ¼ lb. $MnSO_4$	4	Green	57	77	63
None, orchard No. 3	2	Green	52	67	59
None, orchard No. 4	4	Green	61	142	91

Plot No. 9

In order to obtain information on the amount of manganous sulphate that can be used with safety, two sprays at 7-day intervals were applied to healthy pear, apple, peach, and apricot trees in the latter part of August using 5 pounds Tecmangam in 100 gal. of water. No adverse effects were observed on the foliage or fruit at picking time.

The measurements on soil acidity which were made on several of the above plots disclosed that the pH of the top soil (0 – 6″) varied from 7.2 – 7.9 and of the sub-soil (6″ – 12″) from 7.2 – 8.0. The severity of the manganese deficiency was greater at the higher values.

In addition to these control experiments, observations on tree condition and leaf analyses were made on four peach trees which received a single spray treatment in the 1950 season, of 1 pound manganous sulphate in 100 gal. of water. These trees developed the deficiency symptoms again in 1951 and to a degree approximately the same as in the previous year. The leaves for analyses were collected in October and the results are presented in Table No. 2. It is to be noted that their manganese content at that time was approximately the same as that found in untreated checks.

DISCUSSION

Symptoms of manganese deficiency, characterized by small irregularly shaped areas, light green in colour, and appearing in the marginal and interveinal areas of leaves have been previously described (1) for apple, peach, and apricot. These symptoms have now been found on 14 other species of plants and whereas previously it was believed that the occurrence was of a local nature, the deficiency is now known to occur in many widely separated areas of the Okanagan and adjacent valleys in British Columbia.

Severe symptoms have been recognised on some species. A chlorotic condition, which may be quite easily confused with lime-induced chlorosis, has been observed in some localities and it has now been shown that it is caused by a severe manganese deficiency. On peach leaves, a shot-hole condition is commonly found, some leaves may be small, die-back of twigs may occur, and eventually the affected tree may die. On Chinese chestnut, the symptoms of a severe manganese deficiency are striking and are characterized by an inward and upward rolling of the leaf margins.

The manganese content of leaves from several species on which manganese deficiency symptoms were in evidence was determined and compar ed with that present in healthy leaves. It was found that symptom expression was associated with a low manganese content.

Control experiments were confined to tests with manganous sulphate sprays using Tecmangam (67 per cent manganous sulphate). The results indicated that in all trials, even in which as little as a quarter-pound Tecmangam in 100 gallons of water was used, recovery of moderately affected trees was marked. In cases of severe deficiency, 2 pounds in 100 gallons were more effective, a second spray speeded recovery, but at the end of the growing season no difference could be seen between the plots which had received either one or two sprays.

The safe upper limit for the amount of manganous sulphate was not determined even though 2 sprays, 5 pounds Tecmangam in 100 gallons of water, were applied at weekly intervals to the foliage and fruit on peach, apricot, apple, and pear trees.

To determine the compatibility of manganous sulphate with DDT and Parathion, spray mixtures of these materials were used in some orchards. Since the results indicated that the symptoms of manganese deficiency disappeared and the insect population on the experimental plots compared favourably with that in check plots, it was concluded that these materials are compatible under the conditions of the experiment.

ACKNOWLEDGMENT

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COMPARISON OF METHODS OF MECHANICAL ANALYSIS OF SOILS

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ABSTRACT

The pipette method, long recognized as an accurate way of determining soil texture, is time-consuming while other methods, though perhaps less accurate, are more rapid. The authors studied the Casagrande, the Bouyoucos, and the pipette methods, giving special attention to some of the time-consuming steps in the pipette procedure. It was found that the Bouyoucos and Casagrande methods give a lower percentage of clay than the pipette method if either the clay content or the organic matter content of a soil is high. Differences of over 20 per cent were observed. When soils were pre-treated with hydrogen peroxide the Bouyoucos method gave higher percentages of clay than the pipette while the Casagrande method gave lower percentages. Differences in percentages of sand found by the various methods were not large. The authors concluded: that peroxide treatment was essential, regardless of the method used, for all soils containing appreciable amounts of organic matter; that the Casagrande method gives too low a percentage of clay, and with peroxide treatment, is too tedious a method for practical use; that the Bouyoucos method could be used as a rough analysis only for soils low in organic matter; that the pipette method results in too low a percentage of clay due to oven-drying the sample. A revised procedure is suggested.

INTRODUCTION

The accurate determination of the textual class of a soil in a minimum of time continues to be a problem. Numerous methods have been proposed during the last half-century, only to be discarded in favour of simpler or more accurate techniques. This paper reports a comparison of recent techniques using a wide variety of Alberta soils.

The procedure most widely accepted among agriculturists at the present time is referred to as the pipette method. This method, described in detail by Olmstead *et al.* (10) in 1930, and revised and described by Kilmer and Alexander (9) in 1949, is recognized as an accurate method but has been criticized because of the length of time required to complete an analysis.

Another procedure used by many agriculturists is that first advocated in America by Bouyoucos (3), the hydrometer method. Bouyoucos has recently published a revised technique for this method (4).

Bouyoucos gives data comparing the pipette and hydrometer methods. These can be shown on a soil-texture triangle to illustrate the amount of variation for each soil. Figure 1 shows the data given by Bouyoucos comparing the two methods. It can be seen that the hydrometer method tends to yield a higher percentage of clay, the differences amounting to over 10 per cent. However, in fifteen cases out of nineteen, the two methods agreed as to soil class.

The soil specialists in the civil engineering field here use neither of the above two methods. A modification of the Bouyoucos hydrometer method as described by Casagrande and Fadum (6) has been adopted. Its theory

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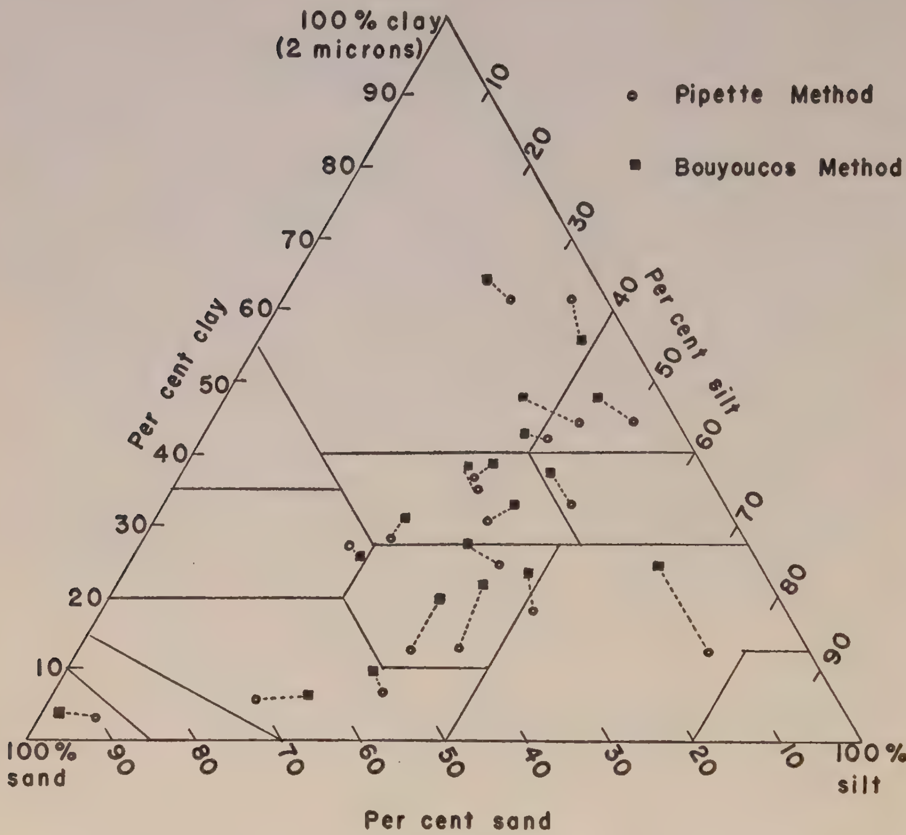

FIGURE 1. Soil-texture triangle showing variations in mechanical analysis by the hydrometer and pipette methods according to data of Bouyoucos (4).

and description is reported by Wintermyer and Willis (17), Willis, Robeson and Johnston (16), and Thoreen (14). Their pretreatment of the soil is similar to that recommended by Bouyoucos, their major change being a series of hydrometer readings up to 24 hours after stirring the suspension. Then, by an application of Stokes' law, a curve is drawn showing the percentage of particles finer than a given size in the sample. It must be noted that this test is used almost completely in the analysis of sub-soils, samples that are therefore free from the large amounts of organic matter found in the samples with which the agriculturist must deal.

This hydrometer method, with slight modifications, was selected by Bowser (5) for analyses of some Alberta soils, Casagrande's nomographic chart being used for a rapid solution of Stokes' law. Bowser then compared this method with the pipette method, and found reasonable agreement, the greatest differences being in the coarser fractions. This hydrometer method, being simpler and shorter than the pipette method, though admittedly not as accurate for surface soils, has been in common use, therefore, in the soils laboratory here.

Both pipette and Casagrande methods depend on an application of Stokes' law, a step that can be taken only if several assumptions are made (*see* Baver (1)). A further difficulty in applying Stokes' law is discussed by Day (7), who suggests a more accurate method for calculating the depth of settling of particles of a given size when using the hydrometer.

Several factors in the pre-treatment of a soil for mechanical analysis have been studied extensively. Olmstead (10) gives an extensive review of them, concluding that hydrogen peroxide treatment, washing to remove soluble salts, and use of a dispersing agent are essential steps in preparing a soil for analysis. Bodman (2) had pointed out earlier the need for taking into account the kind of soil with respect to organic matter content and calcium content. Puri (11) boiled soil samples after adding $(NH_4)_2CO_3$, and then added NaOH or LiOH to bring about dispersion. He reported success with all types of soil. Later Puri and Sarup (12) reported that alkaline potassium permanganate and hypobromite were both more effective than the peroxide treatment in removing organic matter. Thomas (13) experimented with methods of dispersion and concluded that the best way to counteract replaceable bases in the soil was to treat with dilute acid and then use sodium carbonate for stabilizing the dispersed particles. Gollan and Codoni (8) worked out a technique including boiling, HCl treatment, washing, and pH adjustment with NaOH but they concluded that a given technique does not cause complete dispersion in every case. Tyner (15) demonstrated the superiority of sodium hexametaphosphate (Calgon) as a dispersing agent.

MATERIALS AND METHODS

Soil samples used for this study were selected from those collected mainly by the Dominion Soil Survey field men. As shown in Table 1, the soils represent a cross-section of the major soil zones in Alberta and of various horizons in soil types found in each zone.

TABLE 1.—NUMBER OF SOIL SAMPLES ANALYSED

Zone	Soil horizon						Tills	Total
	A	A_2	B	SO_4	C	D		
Brown	5	4	10	13	3	10	—	45
Dark brown	2	—	2	4	2	3	—	13
Black	12	4	19	10	5	—	—	50
Transition	6	2	6	—	—	—	—	14
Grey wooded	1	7	5	1	—	—	—	14
Miscellaneous	—	—	—	—	—	—	7	7
Totals	26	17	42	28	10	13	7	143

Thirteen out of the fourteen samples of grey wooded soil are of particular interest because at the time they were taken, representatives of the United States Soil Survey took duplicate samples for pipette analyses in their own laboratory. It was thus possible to make a rough comparison between pipette analyses made in Alberta and those made in Maryland.

While the chief object of the study was the comparison of several methods, there were several steps in the procedures that were checked by trying different techniques. The weight of sample used, the time of stirring, the condition of the impeller on the stirring machine, shaking as compared to stirring, and the amount of variation with each method were points that received attention.

The methods of analysis used were as follows:

1. *Pipette Method*
   The method described by Kilmer and Alexander (op. cit.) was used with one modification. Instead of filtering with a Pasteur-Chamberlain filter, the suspensions were allowed to settle for 24 hours and the clear supernatant liquid drawn off by suction. A drop or two of dilute HCl was added to the suspension to ensure the settling out of the clay in the time allowed. In the later stages of the study a centrifuge was used successfully to replace the 24-hour periods of sedimentation. A clear supernatant liquid was used as a criterion for completeness of sedimentation in both methods. In the final washing HCl was omitted and a longer period of centrifuging used to complete the sedimentation.
2. *Hydrometer Methods*
   (*a*) Bouyoucos method (4) was followed. The dispersing agent used was the same as in the pipette method and the other methods described below, i.e. 10 ml. of a solution containing 35.7 gm. sodium metaphosphate and 7.94 gm. sodium carbonate per litre. A constant temperature bath was used so that no temperature corrections were necessary.
   (*b*) Bouyoucos method as in (*a*), but following the same pretreatment of the soil as in *pipette* method.
   (*c*) Bouyoucos method, as in (*a*), but including an initial treatment with HCl to decompose carbonates. This method was used only on selected soils from the B, SO_4 and C horizons which were high in lime or gypsum.
3. *Casagrande Methods*
   (*a*) The method described by Casagrande (op. cit.) was the basis for this technique. This method included no acid treatment, no peroxide treatment, and no oven drying.
   (*b*) The method as in (*a*) was used except that the soil was pre-treated with H_2O_2, washed and oven dried.
   (*c*) The method as in (*a*) was used, following HCl treatment, with the same samples tested by the Bouyoucos-plus-HCl treatment.

EXPERIMENTAL RESULTS

Amount of Variation in Each Method

Twelve samples of a well-mixed clay loam were analysed by the pipette method, twelve samples of a loam by the Bouyoucos method, and twelve more samples of this loam by the Casagrande method. The variation in the twelve clay percentages for each soil was found to be quite small. All three methods showed the majority of the samples falling within the range average plus or minus one per cent. The variations in sands and silts were of the same order. All three methods therefore may be considered to be reproducible to the same extent.

A comparison of pipette analyses at this laboratory with those made in the United States on the same soils, the grey wooded soils, is given in Figure 2. Although these analyses represent duplicate samples from the same site and not two samples from a well-mixed composite, which would have been more desirable, the agreement seems to be good. Some error may have been made in the case of the one sample, which is obviously out of line with the rest, an error which may be explained by the fact that these were samples of the B_{Ca} horizon. In view of the general agreement, however, the pipette method is used as a basis in this study for comparing the other methods.

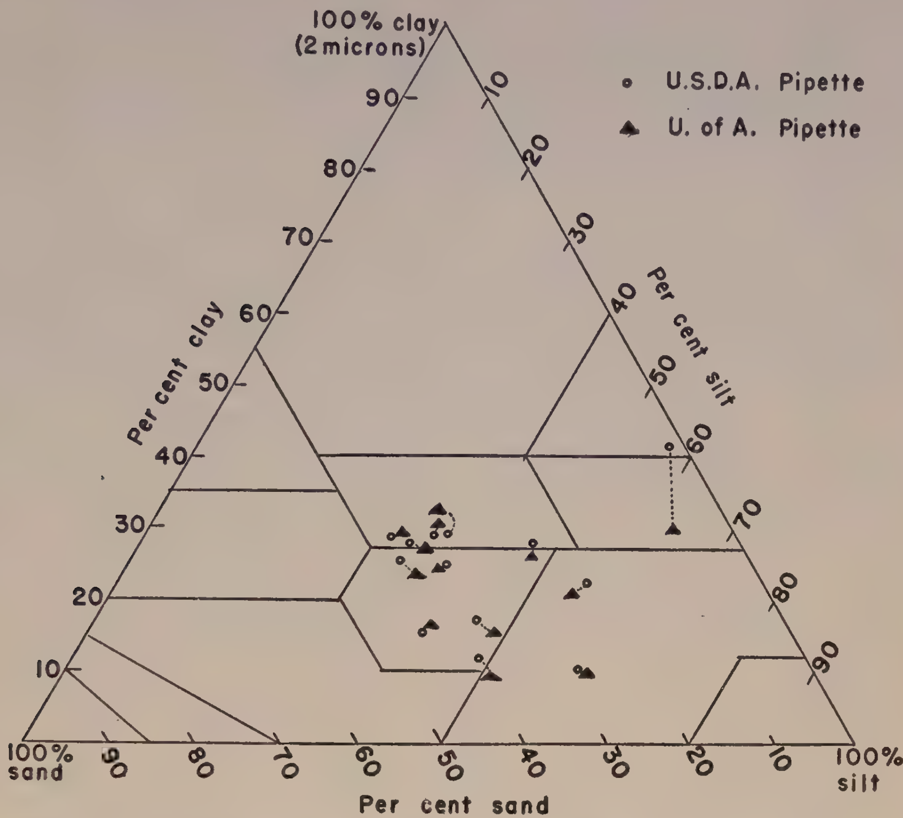

FIGURE 2. Comparison of pipette analysis made at University of Alberta and at Beltsville, Maryland, on duplicate samples of grey wooded soils.

Literature on the Bouyoucos method frequently refers to the importance of the condition of the impeller on the stirring machine. This was checked at this laboratory, using four machines with impellers varying from new to badly worn. Twelve samples of a well-mixed loam were used, three on each stirring machine. No consistent differences were noted.

The Casagrande method requires a period of stirring related to the cohesive quality of a soil, and Bouyoucos likewise recommends from 6 minutes for sandy soils up to 25 minues for heavy clays. Using the Bouyoucos method in this laboratory on samples of a well-mixed loam to sandy loam soil showed an increase in clay content as stirring time increased from 4 minutes to 20 minutes. The greatest increase, about 2 per cent clay, resulted from increasing the stirring time from 4 to 12 minutes. The weight of sample used, whether 50 grams or 100 grams, was found to have a more important effect on the analysis than stirring time. Since the effect of prolonged stirring does not appear to cause large increases in clay content, the Bouyoucos method of dispersing with the stirring machine was compared with the pipette method of shaking for 16 hours. Twelve samples each of a light loam and a clay loam were analysed by the pipette method, half in each case being stirred and the other half shaken. The

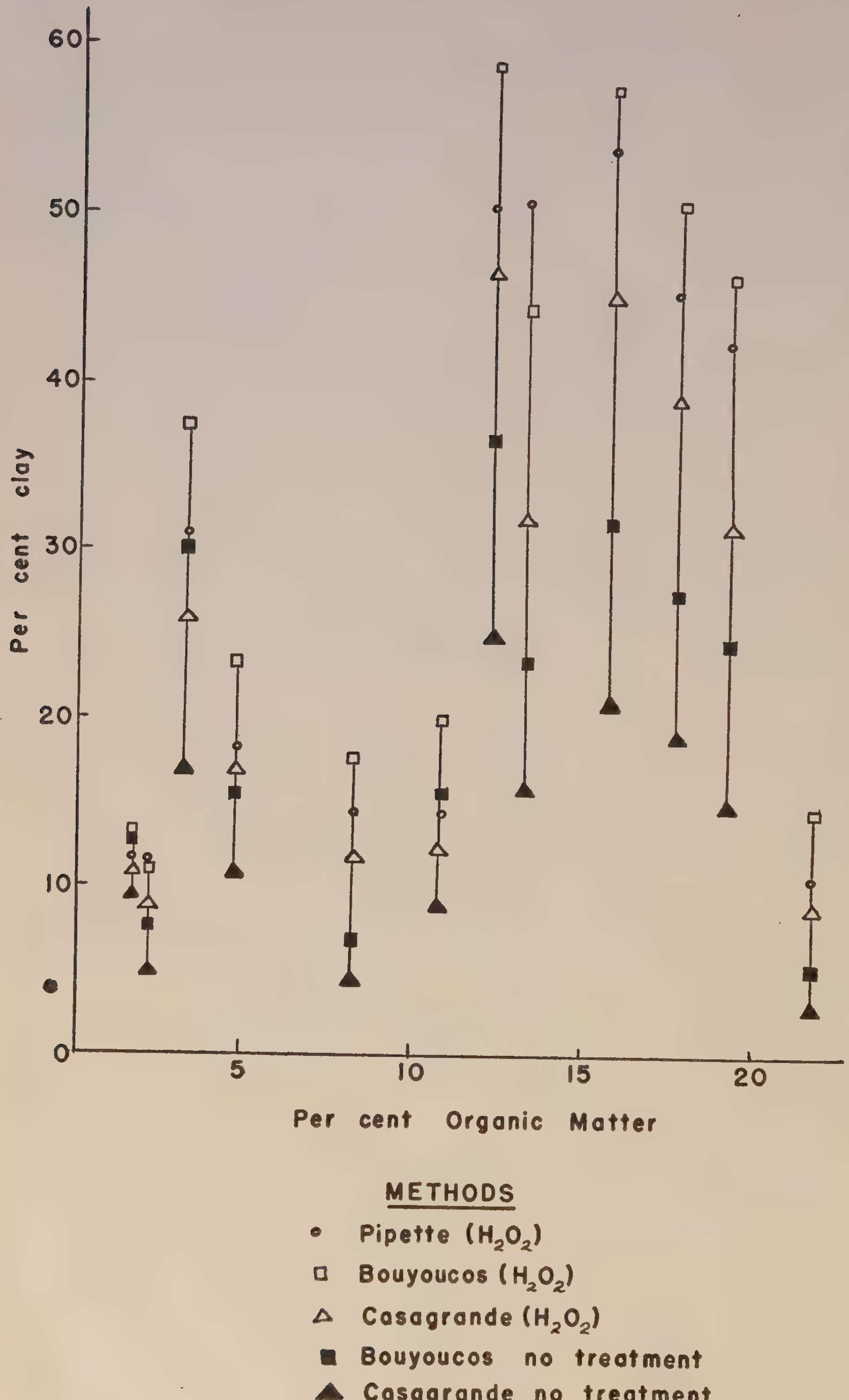

FIGURE 3. Clay content of twelve A_1 horizons by different methods showing effect of organic matter and per cent clay.

stirred samples tested 1 per cent more clay, indicating not abrasion, but better dispersion, since some of the shaken samples frequently showed flakes of clay still cemented together on wet sieving. Stirring time used was 6 minutes for the light loam and 10 minutes for the clay loam.

Comparison of Analysis of Samples from the Various Horizons

A_1 Horizon

The effects of the peroxide treatment on the percentage of clay as found by the various methods are shown in Figure 3. Results for representative samples using five of the different methods are compared. Note the effects of organic matter content and percentage of clay in the soil on the response to the peroxide treatment. Where both are high all methods show wide variations from the pipette method. Where the percentage of clay is low the methods compare fairly well, even with extremely high organic matter; where the soil is heavy textured the methods differ widely, even with soils of low organic matter content. It is apparent that neither the Bouyoucos nor the Casagrande method is consistently close to the pipette method. Both methods give better results after H_2O_2 treatment but the differences are still large.

The percentages of sands in the A horizons show two points worth noting. First, all methods using H_2O_2 are in closer agreement as to per

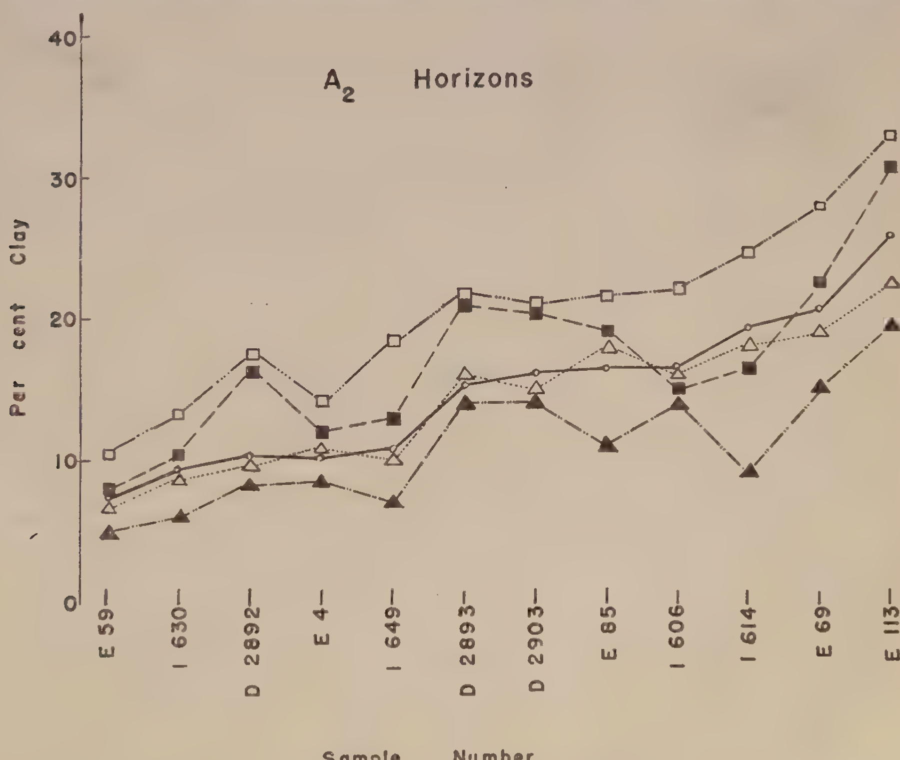

FIGURE 4. Clay content of twelve A_2 horizons by different methods. Symbols as in Figure 3.

cent sand than as to per cent clay or silt. Second, the pipette data for per cent sand appear to be high relative to the other methods for light-textured soils. The latter might be explained by the difficulty of removing all the silt from a large amount of sand in the wet sieving step of the pipette analysis. As might be expected the black soils showed much higher percentages of sands when no H_2O_2 was used.

A_2 Horizon

These show a closer agreement of the various methods. The A_2 horizon is low in organic matter and as might be expected H_2O_2 treatment affected the per cent clay to a lesser degree. (See Figure 4.) The agreement between the pipette method and Casagrande with H_2O_2 seems to be good but when per cent sand and silt are taken into account the agreement is only fair. Examining all 17 of the A_2 analyses shows that the Bouyoucos method, with or without peroxide, gives too high a percentage of clay while the Casagrande too low a percentage. The Bouyoucos method agrees with the pipette as to per cent sand but is lower in silt; the Casagrande method agrees as to per cent silt but is higher in sand. The differences average about 5 per cent.

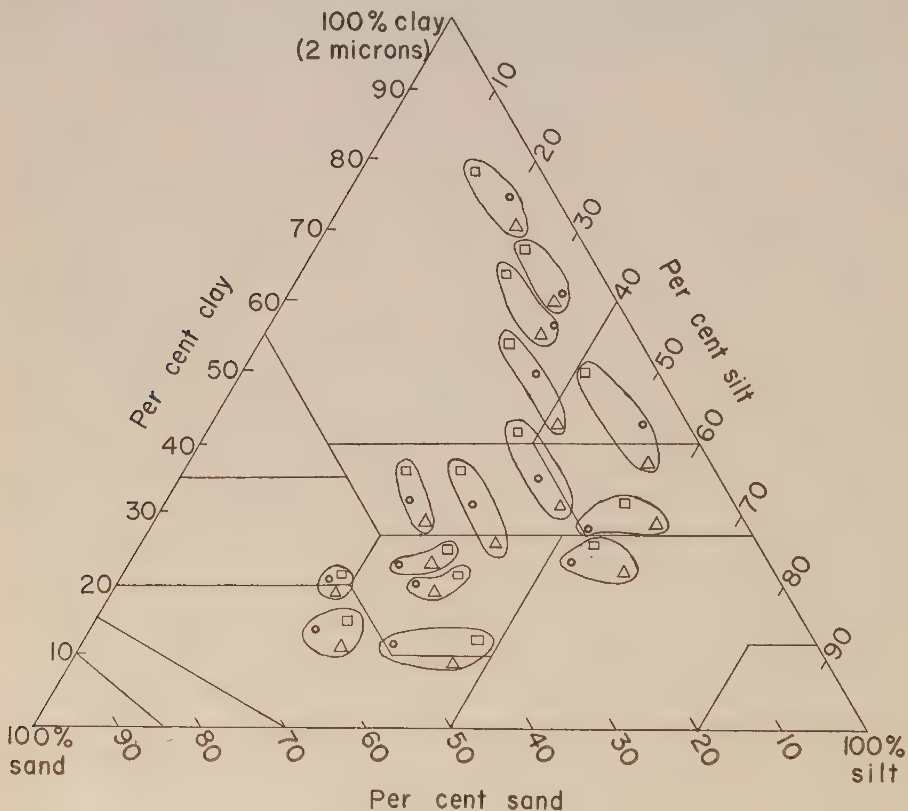

FIGURE 5. Soil-texture triangle showing analyses of fifteen B horizons after peroxide treatment. Symbols as in Figure 3.

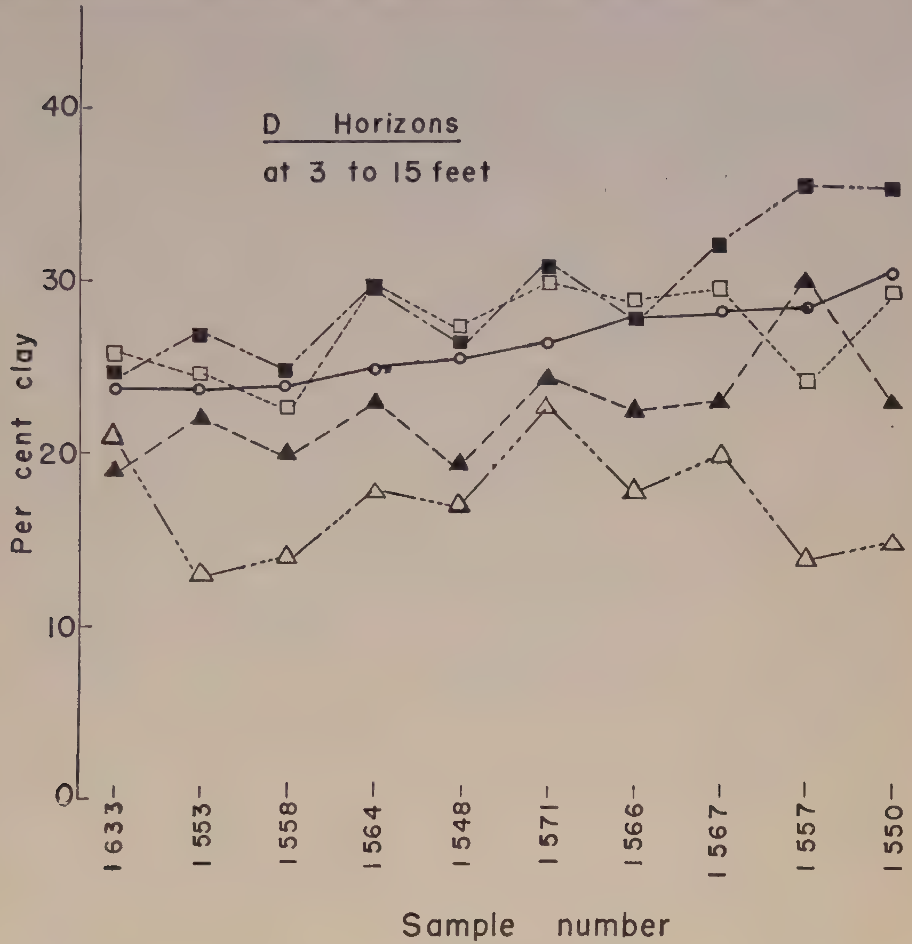

FIGURE 6. Clay content of ten D horizons by different methods. Symbols as in Figure 3.

B Horizon

As indicated in Table 1 most of the samples analysed were from this horizon. The analyses found by the three methods using H_2O_2 were plotted on soil texture triangles and definite trends were indicated. Figure 5 shows 15 representative soils plotted on a single triangle. Note the general agreement of the methods as to per cent sand where the percentage of sand is low, and their divergence when it is high. Again it appears that the pipette method may be in error when large amounts of sand are present. Quite noticeable is the tendency for increasing difference in per cent clay found by the different methods as clay content of the sample increases.

C and D Horizons

These are considered together since the methods showed similar results in the two horizons. These soils are almost free from organic matter and the effect of H_2O_2 treatment is therefore interesting. It will be recalled that after H_2O_2 treatment the samples are washed and then oven-dried at 105° C. so that these other factors, washing and drying, may have affected

the results. In general all methods agreed as to per cent sand, the greatest range for a single sample being 6 per cent. The per cent clay, however, showed greater variation as will be seen by studying Figure 6. The reason for the low readings for the Casagrande-peroxide method may be the oven-drying which led to greater difficulty in dispersion. In the Bouyoucos method the clay is determined by the hydrometer reading two hours after shaking, while in the Casagrande method the clay is determined by a reading some 16 hours after shaking. If dehydration causes a cementation of the fine clays into coarser clay particles that are difficult to disperse, we would expect the two Bouyoucos methods to be in closer agreement than the two Casagrande methods. This is seen to be the case in Figure 6.

Horizons with Salt Accumulations

The most conspicuous difference in the methods used for soils high in salt content concerned flocculation. None of the 10 gm. samples analysed by the pipette method flocculated while over 50 per cent of the 50 and 100 gm. samples analysed by the other methods, including the HCl treatment, flocculated. This difference was, no doubt, due to either the more efficient removal of soluble salts from the smaller soil samples, or the fact that the 10 ml. of dispersing agent was inadequate for the large samples of soils. Perhaps both factors were involved. For the thirteen samples that did not flocculate following HCl treatment the analyses were plotted on a soil-texture triangle. No consistent trends, such as those shown in Figure 5, could be observed. The Casagrande-plus-HCl method gave the lowest percentage of clay in ten out of the thirteen cases; the Bouyoucos-plus-HCl method gave the highest percentage in seven of the thirteen.

Samples of Glacial Till

All of the till samples were analysed by the pipette method and by the standard Bouyoucos and Casagrande methods. One sample was a high lime till and was treated with HCl but this removed so much of the sample that not enough was left for analysis. Another sample was bentonitic and flocculated in all cases except where the pipette technique was used. The results for the other five samples showed the Bouyoucos method giving up to 5 per cent more clay and the Casagrande up to 11 per cent less clay than the pipette method. The percentages of sand were similar for all methods.

TABLE 2.—VALUE OF CORRELATION COEFFICIENTS

Methods of analysis compared	A horizon 12 samples	B horizon 39 samples
Pipette and Bouyoucos	0.90	0.99
Pipette and Bouyoucos plus H_2O_2	0.99	0.99
Pipette and Casagrande	0.89	0.98
Pipette and Casagrande plus H_2O_2	0.98	0.96
Bouyoucos and Bouyoucos plus H_2O_2	0.91	0.99
Casagrande and Casagrande plus H_2O_2	0.90	0.95
Bouyoucos plus H_2O_2 and Casagrande plus H_2O_2	0.99	0.99

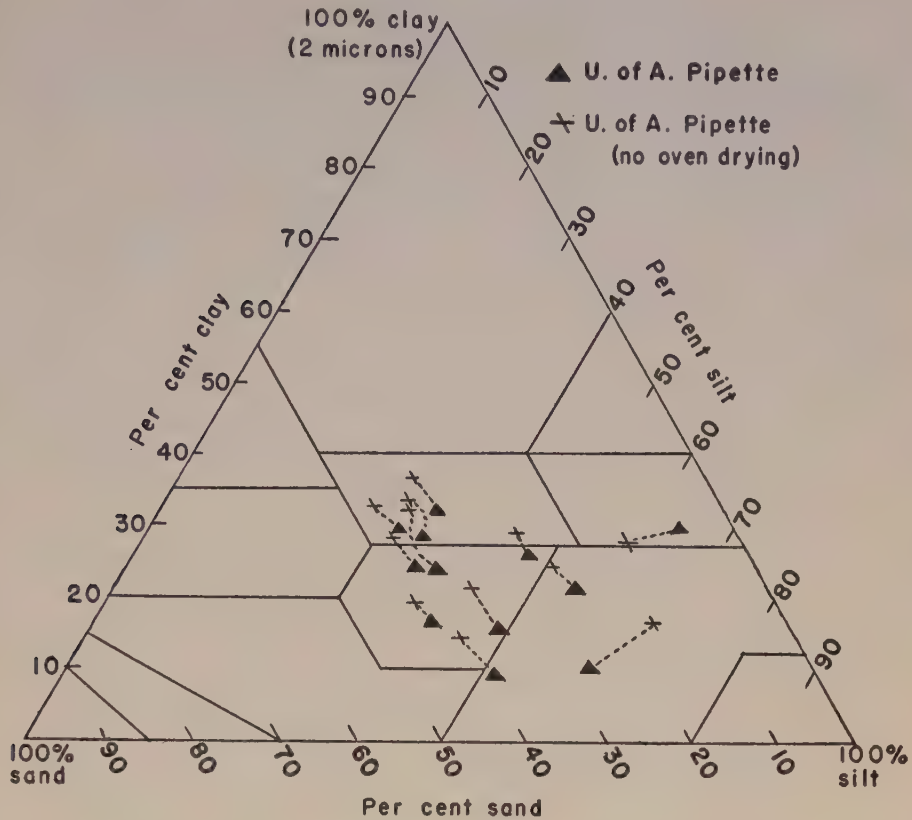

FIGURE 7. Soil-texture triangle showing effect of oven-drying in the pipette procedure.

Statistical Analysis

The correlation of the various methods was studied for samples of the A and B horizons. Values of the correlation coefficient were found to be very high and highly significant in all cases. The comparisons and corresponding r values are shown in Table 2. This table shows that the different methods are more likely to agree if the organic matter in the soil is low or if it is first destroyed by H_2O_2.

Effects of Oven Drying in the Pipette Method

Twelve of the grey wooded soils reported in Figure 2 were analysed by the pipette method with the oven-drying step omitted. A second sample of each soil was carried through the procedure and oven-dried to enable a calculation of the oven-dry weight of organic-matter-and-salt-free soil in each sample. Results are shown in Figure 7. The SiCL sample was erratic due to its calcareous nature. The others show that oven-drying causes a cementation of clay particles into aggregates of silt size that are not dispersed by the shaking procedure recommended in the pipette method.

DISCUSSION AND CONCLUSIONS

A comparison of the Bouyoucos, Casagrande, and pipette methods of mechanical analysis of Alberta soils shows none of these methods infallible. The first is a satisfactory approximation only with soils low in organic matter, say less than 4 per cent. The second is inaccurate for soils containing organic matter and too laborious when the peroxide treatment is added to the procedure. The pipette method, as written up by Kilmer and Alexander (9) is time-consuming and subject to errors as a result of oven-drying which causes a cementation of clay particles, inadequate dispersion of oven-dried samples when a shaking machine is used, and incomplete removal of all silt and clay in the wet sieving step.

The authors conclude that the pipette method with several modifications should be used. These changes would greatly speed up the analysis without a serious loss of accuracy. The following changes are suggested:

1. Weigh out an extra sample for determining oven-dry weight of organic-matter-and-salt-free soil, so that the main sample need not be oven-dried.
2. Use a centrifuge with 100 ml. tubes for washing and removal of dissolved organic matter and salts instead of filtering.
3. Use an electric stirring machine for dispersing instead of a shaker left to run for 16 hours.
4. Use a constant temperature bath to simplify pipetting technique and avoid errors due to temperature differences and the need for temperature corrections.
5. If there is less than 40 per cent sand in a sample there is no point in separating the various sand fractions from one another and where there is over 40 per cent a visual inspection of the various fractions rather than weighing can usually pick out the dominant fraction. This is all that is desired in most mechanical analyses for soil classification.

With these suggested changes the authors feel that the pipette method would be speeded up and simplified with possibly an improvement in accuracy.

ACKNOWLEDGMENT

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OBSERVATIONS ON THE MINERAL METABOLISM OF PULLETS

IX. THE EFFECTS OF ESTROGEN AND ANDROGEN ADMINISTERED SEPARATELY ON THE RETENTION OF CALCIUM BY THE SEXUALLY IMMATURE PULLET[1]

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ABSTRACT

An experiment is described in which sexually immature pullets were treated with either (a) no hormones, (b) androgen, (c) estrogen or (d) estrogen plus androgen, given concurrently.

Estrogen plus androgen increased average daily calcium retention to a level significantly higher than did the other treatments, confirming previous work. Estrogen or androgen increased average daily calcium retention slightly but significantly. There was a significant interaction of estrogen and androgen in regard to the large increase of retention evoked by estrogen plus androgen.

INTRODUCTION

The pullet displays an increasing daily retention of calcium and phosphorus over a period of some two weeks before laying her first egg (9, 3). In the normal pullet this increase is superimposed on the existing calcium retention associated with growth, which is far from complete at puberty. Administration of estradiol dipropionate to adult male pigeons decreases calcium excretion (2). The daily retention of calcium by sexually immature pullets can be increased significantly by injections of estradiol dipropionate provided testosterone propionate is administered concurrently (5, 6). In the latter experiments neither androgen alone nor estrogen alone evoked a statistically significant increase in the calcium retention.

On the basis of these observations, Common, Rutledge and Hale (6) suggested that the increasing daily retention of calcium before laying ("pre-laying storage") is caused by endogenous androgenic activity as well as estrogenic activity. It is well known that androgenic activity is in evidence in the puberal and laying pullet as well as estrogenic activity, for the comb and wattles redden and undergo hypertrophy at this stage. It does not appear yet to be known whether this androgenic influence originates in the ovary or in the adrenal or in both endocrines.

In earlier balance experiments (6, 4) it was noted that the long bones of pullets receiving estrogen only or estrogen plus androgen were more fragile than those of the control pullets. It seemed probable that estrogen alone might have altered skeletal metabolism rather profoundly, although the retention of calcium was not significantly increased by estrogen alone in the experiment in question considered by itself. It was suspected that the turnover of skeletal calcium might have been increased by estrogen even although the daily retention of calcium in the skeleton only increased

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when an appreciable androgenic treatment was given concurrently with the estrogen. This possibility did not seem to be contradicted by any-thing in the literature, as reviewed by Gardner and Pfeiffer (7) and by Tyler (13).

Accordingly the experiment has been repeated, and at the same time extended by appropriate labelling of the dietary calcium with radiocalcium. The experiment thus comprised balances of labelled calcium and determination of the amount of labelled calcium retained by the skeletons as well as total calcium balances.

The present paper is limited to a consideration of the total calcium balances. The results of the studies in so far as the use of radiocalcium is concerned will be described in a subsequent paper.

MATERIALS AND METHODS

Experimental Birds

The *desiderata* in selection of pullets for such experiments have been outlined previously (6). In the work now reported the pullets were the offspring of New Hampshire males crossed with Barred Plymouth Rock females.

Experimental Methods

The experiment was carried out in two replicates each comprising four groups of three pullets. The twelve birds in a replicate were housed individually in metabolism cages in a room equipped for experiments involving the use of radioactive isotopes. The birds were assigned to their cages at random. They received equal amounts daily of an experimental diet having the following composition:—

	Parts by Weight
Ground wheat	42
Ground oats	28
Wheat bran	5
Skim milk powder	4
Soya bean oil meal	9
Linseed oil meal	3
"Vitagras" (dehydrated cereal grass)	1.5
Common salt	1
Fish oil (2400A, 400D per g.)	0.5
$Na_2HPO_4 \cdot 12\ H_2O$	3
$MnSO_4 \cdot 4\ H_2O$	50 p.p.m.

This mixture had the following analysis:— Crude protein, 16.1 per cent; Ca, 0.18 per cent; P, 0.74 per cent.

Each day each pullet was given a weighed amount of this mixture to which was added a weighed amount of calcium carbonate U.S.P. This method of adding the calcium supplement daily in individual weighed amounts is laborious, but it avoids the serious risk of error due to settling and imperfect bulk mixing.

Each morning the droppings for the preceding 24 hours were removed individually from the glass collecting plates, dried, ground, equilibrated with laboratory air, weighed and bottled for subsequent analysis. The birds were fed so as to maintain the individual intakes of the diet for a given day as nearly equal as possible. The daily allowance was divided between two feeds, one given at approximately 7.00 a.m. and the other at approximately 5.00 p.m., so as to avoid undesirable gorging. During the experiment the average daily consumption was approximately 70 gm. per day along with 2.50 gm. calcium carbonate.

After they had settled in their surroundings, the birds were placed on balance for a preliminary period of 5 days. They were then given the following treatments by intramuscular injection on alternate days over an experimental period of 11 days (six injections in all):

Group 1. Sesame oil, 0.5 ml. on alternate days.
Group 2. 0.75 mgm. testosterone propionate (TST) in 0.5 ml. sesame oil.
Group 3. 1.00 mgm. estradiol benzoate (ODB) in 0.5 ml. sesame oil.
Group 4. 1.00 mgm. ODB plus 0.75 mgm. TST in 0.5 ml. sesame oil.

The experiment was terminated by killing the birds on the morning of the day after the sixth and last injection. During the final balance day the calcium carbonate was labelled with radiocalcium. The balance data for the preceding ten days were considered separately and form the basis of the present paper. The data for the single balance period following the sixth and last hormone injection will be considered in a subsequent paper.

The entire experiment was then replicated with a second lot of twelve birds similar to those used in the first replication. It may be remarked here that the divergences between the numerical data for calcium retention in the two replicates were highly non-significant statistically. Hence the data for all the pullets could be considered together as data from a single experiment.

EXPERIMENTAL RESULTS

The average results for live weights, oviduct weights and serum calcium are set out in Table 1. The ovaries did not display the slightest macroscopic

TABLE 1.—EFFECTS OF GONADAL HORMONES ON LIVEWEIGHT GAINS, OVIDUCT WEIGHTS AND SERUM CALCIUM LEVELS OF THE EXPERIMENTAL BIRDS

Average date. Six pullets per group

	Group 1 Control	Group 2 Androgen	Group 3 Estrogen	Group 4 Estrogen + Androgen
Initial live weight, kgm.	0.99	1.00	0.96	0.99
Final live weight, kgm.	1.22	1.26	1.19	1.24
Liveweight increase, kgm.	0.23	0.26	0.23	0.25
Oviduct weight, gm.	0.10	0.10	9.23	16.3
Serum Ca, mgm./100 ml.	12.0	12.3	45.5	48.3

TABLE 2.—EFFECTS OF GONADAL HORMONES ON THE AVERAGE DAILY RETENTION OF CALCIUM BY THE SEXUALLY IMMATURE PULLET

Group		1 Control	2 Androgen	3 Estrogen	4 Estrogen + Androgen
Treatment		Nil	5 × 0.75 mgm.TST**	Nil	5 × 0.75 mgm.TST
		Nil	Nil	5 × 1.0 mgm.ODB*	5 × 1.0 mgm.ODB.
Average daily calcium retention, mgm.	Present results: Average of three treatment replicates in each of the two experiments	221	267	286	411
		242	262	274	400
	Previous results (6): Three replicates	256	281	280	398

*Common *et al.* (1948) used estradiol dipropionate (ODP) instead of estradiol benzoate (ODB).
** In one series of four birds Common *et al.* (1948) used a larger dose of testosterone propionate (total dose was 8.25 mgm. and not 4.5 mgm.).

sign of the onset of reproductive activity. The responses of oviduct weight and serum calcium were of the order desired.

The mean daily retentions for treatments in each experiment are presented in Table 2. The mean daily retentions observed in the previous experiment (6) are also given in Table 2 for comparison with the values observed in the present experiments.

DISCUSSION AND CONCLUSIONS

The most casual inspection of the data shows that estrogen plus androgen considerably increased the average daily calcium retention. An inspection of the two sets of data suggested that both androgen alone and estrogen alone might have caused increases of average daily retention of calcium, albeit of a lower order of magnitude than the increase evoked by estrogen plus androgen. The close quantitative correspondence of the average results of the two sets of data was the more impressive in view of the differences in breed and location. Accordingly, the entire data including the comparable data from Common *et al.* (6) were assembled for statistical analysis as shown in Table 3.

The extraordinarily close agreement between the data of Common *et al.* (6) and those of the present experiment is confirmed by the minute value of "F" for variance between experiments. The statistical analysis also shows that the small increases in calcium retention evoked by androgen alone and by estrogen alone are both highly significant. The relatively large increase evoked by estrogen plus androgen is, of course, very highly significant, in confirmation of the previous conclusions, but the previous data by themselves were insufficient to reveal any significance of the single treatments. The rapidity of response to injected gonadal hormones in respect of calcium retention, as previously noted by Clavert and Benoit (2) and by Common *et al.* (6), was confirmed in the present experiment.

TABLE 3.—ANALYSIS OF VARIANCE FOR MEAN DAILY RETENTION OF CALCIUM BY SEXUALLY IMMATURE PULLETS

Combined data of present experiment and experiment of Common *et al.* (6).

Source of variation		D.F.	Mean square	F
Treatments	3		46603.33	38.99**
Androgen		1	5290.00	44.26**
Estrogen		1	67773.00	56.70**
Estrogen × androgen		1	19136.00	16.01**
Replications	8			
Experiments		2	286.00	0.24
Replicates		2	2670.00	2.23
Replicates × experiments		4	748.00	0.62
Treatments × experiments	6		390.83	0.33
Error	18		1195.28	
Total	35			

** Highly significant at P = 0.01.

That estrogen alone might lead to some increase in retention was not altogether astonishing. Bloom, McLean and Bloom (1) secured endosteal bone formation in castrate male pigeons and in intact males by injection of estrogen during periods of sexual inactivity. This effect was slight compared with the marked formation of medullary bone following injection of estrogen into sexually active intact males, but was definite. To the extent that a castrate male may be regarded as comparable with the sexually immature female in respect of hormonal status, estrogen might therefore be capable of stimulating a slight amount of endosteal bone formation. A relatively slight effect of this nature would account for the small increase in calcium retention with estrogen alone in the present experiment. The significance of the effect of androgen on calcium retention is remarkable, especially since androgen, at the levels used, did not produce a measurable effect on the oviducts or serum calcium level. This would appear to be the first occasion on which androgen administered by itself has been observed to affect the calcium metabolism of the sexually immature pullet. The matter will be discussed further in a subsequent paper.

The experiments of Clavert and Benoit (2) and of Govaerts, Dallemagne and Melon (8) are scarcely comparable in view of the use by these workers of male pigeons as negative controls, and in neither case were full balance data recorded. Massive doses of testosterene propionate will increase oviduct weight in the chick (10, 11), but Riddle and Dotti (12) were unable to detect any effect of androgen on the serum calcium of chicks even under massive dosage.

The third moiety of treatment variation is that ascribable to interaction. The data now available provide evidence of a significant positive interaction of androgen and estrogen in regard to calcium retention. The data of the previous experiments by themselves were insufficient to establish this interaction.

SUMMARY

1. Sexually immature pullets were injected intramuscularly on alternate days with 1.0 mgm. estradiol benzoate and 0.75 mgm. testosterone propionate over a period of ten days. These pullets displayed a highly significant increase of average daily calcium retention from 231 mgm. per day in control birds to 407 mgm. per day in the birds treated with estrogen plus testosterone, in close agreement with previous experimental data.

2. Treatment with either estrogen alone (1.0 mgm. on alternate days) or androgen alone (0.75 mgm. on alternate days) over a period of 10 days evoked a significant increase in retention, the increase being of the order of 40 mgm. per day and much lower than that consequent on concurrent treatment with estrogen and androgen.

3. The interaction of estrogen and androgen in regard to increase of daily calcium retention was highly significant.

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A MICROSCOPIC STUDY OF PLATY AND CONCRETIONARY STRUCTURES IN CERTAIN SASKATCHEWAN SOILS[1]

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ABSTRACT

Thin sections of platy A_2 horizons of several Saskatchewan soils which have developed under podzolization or solonization processes were studied. A synthetic resin was used to impregnate and fix the soil aggregates so that slides for microscopic study could be made.

The thin section studies revealed "banded fabric" in the platy horizons of podzolized soils. The platy A_2 horizon of a solonetzic soil revealed an "isoband fabric" as did the A_2 of a podzolic-solonetzic soil studied. "Wrinkle marks" and "invasion amygdali" (concretions) were also noted in samples from A_2 horizons of podzolized soils. A brief discussion of possible modes of formation of these micro-structures as proposed by several authors is included.

It is suggested that the thin section technique might well be applied in studying pore space and channel arrangement in soils, as well as aggregates of all types. It would also probably be useful in studying such matters as the distribution of organic matter within the soil body. This technique might prove of value in attempting to elucidate some genetic relationships of soils in this region.

The method is applicable to unconsolidated rocks as well as to soils.

The macro-structures of soils are readily observable and have been carefully studied, particularly by those interested in soil classification. The soil micro-structure is more difficult to study, although undoubtedly micro characteristics are of great importance in elucidating the factors of structure formation, and their relationships to pedogenic processes. This fact has been realized for many years and research workers have devised various means of attaining suitable methods through which micro-structures might be studied.

In the present study the thin sections technique, as proposed by Kubiena (6), was followed to examine the nature of platy structures of the A_2 horizon in Chestnut Solonetzic, Degraded Chernozem, Grey Podzolic (grey wooded) and Grey Podzolic-Solonetzic soils. An attempt is made to relate "banded fabric" and concretions observed under the microscope to the horizontal platy structures commonly found in the A_2 horizons of these soils.

REVIEW OF LITERATURE

Kubiena published his "Micropedology" in 1937 and this book provides an excellent foundation for the study of soil micro-structures (6). According to this author, as early as 1904 Delage and Lagatu attempted to prepare thin sections of crushed soil by adding hardening substances. Day (3) quotes Pigulevsky's studies of 1914 in which soil clods were impregnated with paraffin wax and naphthalene so that photo micrographs of soil structures were made possible. Volk and Harper (14) used Bakelite varnish No. 1305 as the best obtainable impregnating compound available at that time. Some similar type of compound was apparently used by

[1] Contribution from the Department of Soils, University of Saskatchewan. Presented at meeting of Soils Section, Agricultural Institute of Canada, Ottawa, June, 1952. (Data from thesis submitted by the senior author in partial fulfilment of requirements for the M.Sc. degree.)

[2] Graduate Student, Department of Soils, University of Saskatchewan.

[3] Professor of Soil, Science.

Ross (12) in his search for a satisfactory method of studying friable materials for the United States Geological Survey. Frei (4) studied Swiss soils, using Kubiena's techniques, and later Frei and Cline (5) studied the micropedological characteristics of podzolic soils in New York State.

Bourbeau and Berger (1) introduced the use of the synthetic resin, Castolite*, which was used in this study, as an impregnating material, and Day (3) tested the same material in an evaluation of the polished section technique. Meewis (7) has described a method making use of methyl methacrylate as the impregnating compound which may offer further improvements in studying soil sections microscopically.

METHODS

Selected monoliths of the desired soils were obtained and undisturbed clods removed from the appropriate horizons for study. A record was made of the orientation of each clod as well as its exact location within the horizon of the profile.

A clod of suitable size was placed in a clean 50 ml. glazed porcelain crucible and then thoroughly dried at room temperature. Thorough drying is necessary because the cementing properties of Castolite are reduced in the presence of moisture (2). To prevent premature polymerization the liquid, Castolite, should be stored at about 35° F. Before use the liquid is warmed in a beaker placed in warm water to decrease its viscosity. While warming a catalyst, called "castolite hardener", which hastens polymerization after impregnation, is also added at the rate of eight drops per 100 ml. of Castolite. The Castolite is then poured slowly into the crucible containing the dry and oriented clod of soil. When the soil is completely covered the crucible is placed in a dessicator which is slowly evacuated. This removes the air from the pores and allows entry of the plastic without disruption of the particle arrangement within aggregates. Evacuation should not require more than one hour to complete.

The impregnated sample is allowed to stand undisturbed at room temperature for at least five days and preferably for seven days. After this preliminary hardening, the samples are ready for the "heat treatment". This curing process is accomplished by putting the hard samples into an oven for 30 minutes at 82° C. Castolite has a linear shrinkage of 2.5 per cent which allows easy removal of the casts from the crucibles.

Thin sections are prepared in essentially the same manner as for rocks. Either kerosene or ethyl alcohol were used as lubricants in the cutting process. Thermoplastic cement** is satisfactory for mounting the smooth chip to the glass slide. Kerosene was used as the lubricating liquid in grinding the chip to approximately 0.07 mm. thick for microscopic study. It was found that excess oil could best be removed with a small amount of carbon tetrachloride which does not react appreciably with the Castolite or thermoplastic cement. Cover glasses were fixed with Canada balsam dissolved in xylol.

The method described above is essentially that of Bourbeau and Berger (1) with slight modifications.

* Manufactured by the Castolite Company, Woodstock, Illinois.
** Lakeside Chemical Corporation, 7600 Greenwood Avenue, Chicago, Ill.

The thin sections were studied with a binocular microscope. Micrographs were prepared using Kodak Super XX film in a standard microscope camera on a single ocular microscope. Prints were prepared on a medium contrast glazed paper.

Description of Soils Studied

Profile 1. (Dorintosh Association)—A well developed grey podzolic (grey wooded) soil on a calcareous silty clay, glacial lacustrine deposit. This profile was from a moderately poorly drained flat area.

Profile 2. (Horsehead Association)—A degraded black soil on slightly calcareous glacial till.

Profile 3. (Depression "Bluff" Podzol)—This type of soil occupies small upland depressions and the outer margins of sloughs and meadows within the Black and Degraded Black Soil Zones. The parent material of the soil studied is a calcareous glacial till. The profile occurred in a somewhat poorly drained position near the bottom of a northerly facing slope treed with small aspen.

Profile 4. (Arborfield Association)—A grey podzolic solonetzic soil on a calcareous heavy glacial lacustrine deposit. It is suggested (8) that this complex soil was originally solonetzic later developing podzolic characteristics under invasion of the forest.

Profile 5. (Elstow Association)—A Dark Brown (Chestnut) solonetzic soil on calcareous glacial lacustrine silty deposits. The profile sample was a silty clay loam with weak A_2 development.

More complete information about the soils described may be found in Soil Survey Reports No. 12 and 13, University of Saskatchewan (8, 9).

DISCUSSIONS

Soil Fabric in Relationship to "Platy Structure"*

A. *Banded Fabric:*

The soil constituents shown in the micrographs in Figure 1 show horizontally elongated arrangements which are related to the macrostructure commonly described as "platy structure". To date, there seems to be no clear-cut understanding of the cause of this structure. Peterson (11) at Iowa performed experiments which led him to believe that in essence the amount of kaolinite in the soil controlled the development of platy

* "Soil fabric" is defined by Kubiena as the "arrangements of the constituents of a soil in relation to each other".

FIGURE 1. Micro-photographs showing the fabrics of platy A_2 horizons of selected soils.

A: Profile 1—Banded fabric in A_2 of Dorintosh profile. Dark horizontal bands have sharp lines representing the tops of the band. The dark area grades downward to the lower light colored portion. Dark top part is considered due to accumulation of colloidal clay, sesquioxides and humus. (Magnification $\times$20).

B: Profile 2—Banded fabric in A_2 of Horsehead profile. One complete horizontal band is shown grading in "plasma" (clay, sesquioxides and humus) content from top to bottom. (Magnification $\times$50).

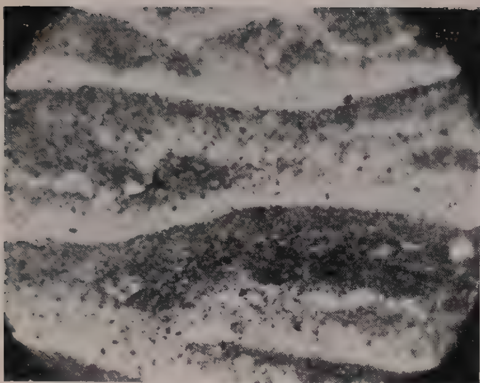
C: Profile 3—Banded fabric in A_2 of Depression ("Bluff") Podsol. Note convex humps developed at top of bands. (Magnification $\times$20).

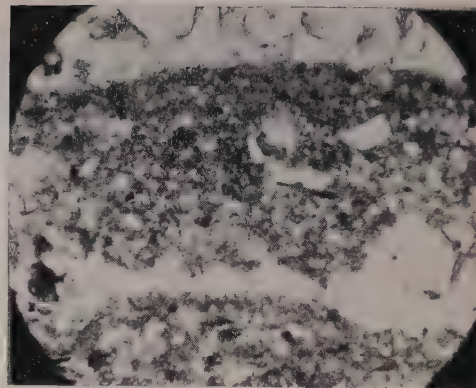
D: Profile 4—Isoband fabric in A_2 of Arborfield profile. Note that the horizontal bands show no gradation from top to bottom. The round black areas are invasion amygdali (concretions). (Magnification $\times$20).

E: Profile 5—Isoband fabric in A_2 of Elstow profile. Note the root cutting across the bands on the left. (Magnification $\times$20).

F: Profile 1—Wrinkle marks in lower A_2 of Dorintosh profile. Note gradation from top to bottom of the wrinkles. Also they are short, pointed and humped towards the top of the bands. (Magnification $\times$20).

NOTE: All photographs are properly oriented so that structures are shown as they would occur in the soil profile.





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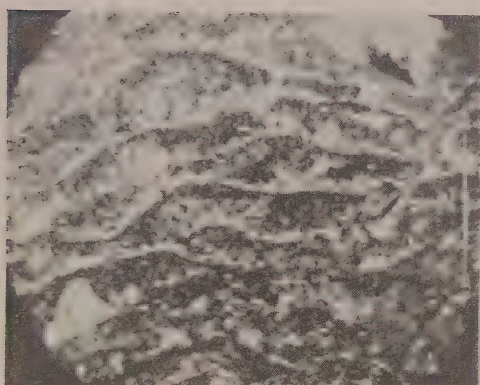

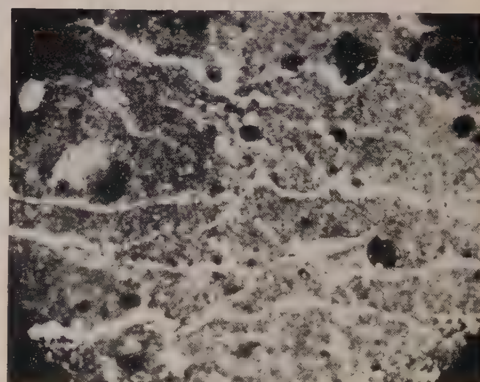

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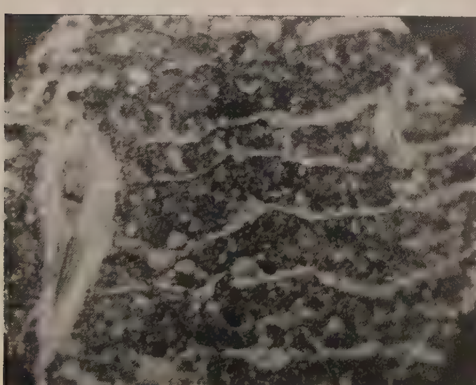

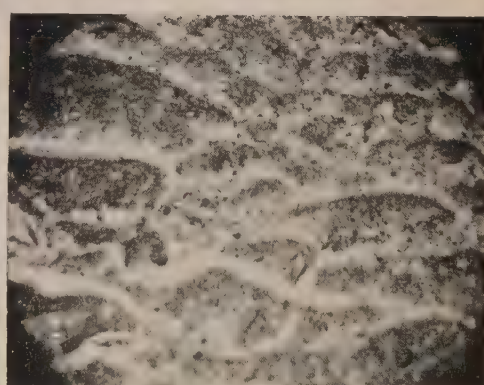

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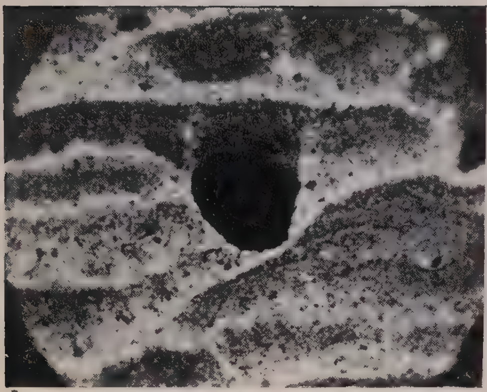

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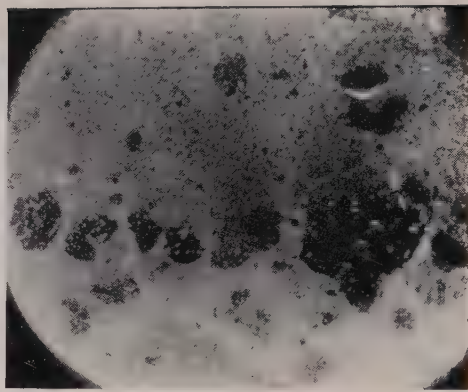

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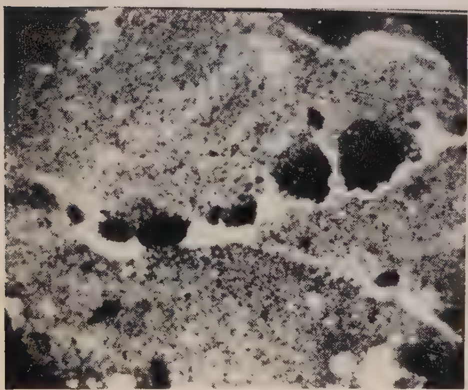

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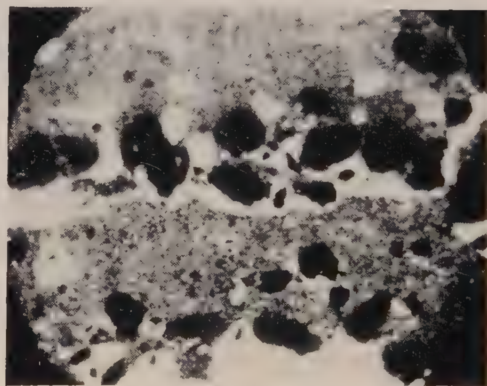

D

FIGURE 2. Micro-photographs showing invasion amygdali in A_2 horizons of Profile No. 1. (Dorintosh)

A: Invasion amygdalus (concretion) at the bottom of a band of banded fabrics in the A_2. Note lack of a sharp boundary at the top and gradation into the top part of the band. (Magnification $\times 20$).

B: A row of invasion amygdali along the bottom of a band in the A_2. Note the poorly defined upper boundaries and the slight concentration of plasma substances in the top of the band below. (Magnification $\times 20$).

C: A row of invasion amygdali with poorly defined upper boundaries in the A_2. (Magnification $\times 20$).

D: Two rows of invasion amygdali parallel to bands of banded fabrics in the A_2. Note shaded areas above some amygdali possibly representing migrating substances. (Magnification $\times 20$).

NOTE: All photographs are properly oriented so that structures are shown as they would occur in the soil profile.

structure. In Saskatchewan the amount of kaolinite found in soils so far examined is very low (15). This fact, among other things, necessitates looking for other explanations.

Sideri (13) produced laminar structure by drying clay gels. His explanation appears to be based on the theory of molecular attraction between soil particles. It has also been suggested that the action of frost might account for platy structures through progressive freezing and ice lensing from the surface downwards. However, platy structures are found in regions where frost action is absent. Kubiena (6) has advanced theories based on his observations which seem to be more logical in explaining some types of platy structure. According to this author, "banded fabric" occurs in "compact" soils which have a uniform skeletal fabric with dissolved or dispersed colloidal materials and which do not possess cleavage blocks or fragments with relatively large channels or cracks between them. The phenomenon can be recognized by banded accumulations of clay, humus and sesquioxides within the profile. This author also suggests drying of the soil from the top down will produce a zone of accumulation of colloidal material at the evaporating surface. This accumulation in turn results in "capillary draft" into the zone causing more colloids to be drawn to the zone. When the adjacent eluvial layer dries out, transportation will be interrupted for a time, but will be resumed at a new evaporation surface within the soil system. Thus Kubiana believes that the Liesegang ring theory may serve as a theoretical basis in explaining the occurrence of layers relatively rich or poor in "plasma" substances which follow one another in a rhythmic pattern through the skeletal material of the soil. The accumulations occur in the unchanged inter-granular spaces which are then more or less occupied by colloidal substances. He points out that "banded fabric" is much different from "laminated fabric" in which the differences between the layers are expressed in changes in regard to the arrangement of the skeletal material itself.

The denser accumulation zone in contrast to the relatively depleted zone forms an easy horizontal plane of parting. The soil mass breaks on these planes forming plates which gives rise to "platy structure". In Saskatchewan, it has been noted that the plates are darker on one side than the other which may be explained by the occurrence of clean skeletal material on one side of the aggregate and skeletal material enriched by soil plasma on the other.

B. *Isoband Fabric:*

Isoband fabric is a term suggested here for bands apparently having complete uniformity in both skeletal material and soil "plasma". The causes of this fabric type are still unknown.

Frei and Cline (5) in their study of Grey-Brown podzolic soils show a micrograph of platy structure occurring in a "B" horizon. These bands show no gradation in texture and these could apparently be classified as of an isoband fabric. In Figure I, photos D and E show this feature in the A_2 horizon of profiles 4 and 5 (Arborfield and Elstow soils). The similarity of the fabrics shown in Figure 1, D and E, appears to offer further evidence that the Arborfield profile was partially developed under solonetzic processes such as were responsible for the profile development of the Elstow soil.

C. *Wrinkle Marks:*

Wrinkle marks are described by Kubiena (6) as being short, pointed, irregular and of rather infrequent occurrence. He attributes their information to the same factors which result in "banded fabric". See Figure 1 (F).

INVASION AMYGDALI (CONCRETIONS)

It is definitely shown in Figure 2, A, B, C, and D that concretions in the A_2 of the Dorintosh profile occur at the bottoms of bands of banded fabric. The reasons for this are not clear. Concretions are more abundant at the bottom of the A_2 and there is evidence that they form after the banded fabric has formed. As the soil dries, aeration would occur first at the bottoms of the bands and along the cleavage planes. Substances such as sesquioxides and humus which form concretions might precipitate under these conditions. When a nucleus is formed, sesquioxides and humus from the top of the band would tend to migrate towards this nucleus with the subsequent wetting and drying of the profile. Peterson (10) has attributed concretionary development to such processes in his study of Tama silty loam. The stained areas at the tops of the concretions shown in the micrographs (Figure 2) suggest that this process of diffusion is still in progress in the soil studied.

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A STUDY OF THE CAROTENE AND CRUDE PROTEIN CONTENT OF ORCHARDGRASS (*DACTYLIS GLOMERATA* L.)

I. VARIATION DUE TO STAGE OF GROWTH, CUTTING MANAGEMENT AND CLONES

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ABSTRACT

A survey was made of the variation in carotene and crude protein content for a selected group of orchardgrass plants that could be accounted for by (*a*) stage of sampling, (*b*) cutting management and (*c*) clones.

The mean values for carotene and crude protein showed marked differences between stages of growth for the ten clones studied. In terms of original values for the vegetative stage, a reduction of 52 per cent in carotene content had occurred up to the time the plants had started to head. From heading to anthesis, the reduction was almost 13 per cent, followed by a marked decline to the seed ripe stage. Crude protein content exhibited similar trends for samplings at different growth stages. Repeated samplings at the vegetative stage of growth resulted in a steady seasonal decline for carotene. The data for two systems of cutting management showed that both carotene and crude protein were significantly higher in the aftermath clippings following hay than in comparable cuts for pasture.

Carotene or provitamin A is a particularly important constituent in forage crops since it is the only one of the important vitamins that the grazing animal obtains solely from the feed consumed. Protein also ranks very high in the needs of live stock and can be supplied in its cheapest form by pastures and preserved forages. Breeding for higher values in particular nutrient constituents has received little attention in forage crops. Extensive analytical data are available with respect to minerals and crude protein in grasses while information on carotene content is more limited.

The published literature would indicate that the crude protein and carotene contents of pasture grasses fluctuate in a rather similar manner. The progressive decline in protein content as grasses approach maturity has been very well established (2, 4, 5, 7, 8). A number of workers (10, 12, 13) have reported a similar relationship for carotene in grass species. There is evidence, too, of a seasonal fluctuation for both constituents. Both tend to be high in the spring, declining during the summer and rising again in the late summer or early fall (3, 4). Pickett (11) found carotene content to be positively correlated with crude protein in bromegrass. Smith and Robb (12) have also reported carotene content to be closely correlated with protein in several grassland species.

In addition to management and environmental factors, striking differences in protein and carotene can be accounted for within a given species as a result of individual variations in growth habit and/or genetic constitution. Christoph (6) observed marked differences in protein content between varieties of orchardgrass and tall oatgrass. Waldron (15) reported marked differences among nine bromegrass clones. Tsiang (14) in a study of several characters in bromegrass obtained marked differences in carotene

[1] Contribution from the Department of Agronomy, The Pennsylvania State College; the U.S. Regional Pasture Research Laboratory, State College, Pennsylvania; and Experimental Farms Service, Canada Department of Agriculture. Authorized for publication June 25, 1952, as Paper No. 1739 in the Journal Series in the Pennsylvania Agricultural Experiment Station.

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content between selected lines. Johnson and Miller (9) investigating selections of Fairway crested wheatgrass and Parkland bromegrass reported highly significant differences in per cent of total carotenoid pigments, beta-carotene and chlorophyll.

From the information cited it would seem that the total nitrogen and carotene content of grasses in general is governed by the interaction of several factors. Therefore an appraisal of analytical data for these constituents should include a consideration of the various factors contributing to the environment as well as to matters such as the age of the plant and the parts analysed. Superimposed on these effects and interacting with them is the inherent genetic constitution of the plant. With these points in mind it would appear that a necessary prelude to an inheritance study concerned with carotene and protein would be a controlled preliminary investigation of the influence of management, time of sampling and maturity differences for the species being studied.

MATERIALS AND METHODS

In order to obtain information useful in the establishment of breeding projects aimed at increasing nutritive value in orchardgrass, a study was made of the variation in carotene and crude protein that could be accounted for by (*a*) stage of sampling, (*b*) cutting management, and (*c*) clones.

Plant Materials

Ten clones of orchardgrass representing two maturity classes, early and late, were selected within four restricted polycross nurseries planted in 1947 and located at the United States Department of Agriculture Regional Pasture Research Laboratory, State College, Pennsylvania. The ten clones used in this study were chosen as being representative of the general type of the entries in the respective nurseries but without prior knowledge of their chemical analysis.

Sampling Treatments

Data for stage of sampling were based on the analysis of the ten clones collected at (*a*) the vegetative stage (height 6-8 inches), (*b*) inception of heading (date first heads emerge from sheath), (*c*) inception of anthesis (date first anthers extruded), and (*d*) seed ripe (heads brown and shedding at tips). The effect of frequency of sampling was obtained for four sampling dates at the vegetative stage on the same plants. The influence of cutting management for nine of the original clones was based on (*a*) cutting at the hay stage (inception of anthesis) followed by close clipping of the aftermath and (*b*) continuous close clipping to simulate pasture. Additional information on sampling methods for carotene was obtained through analysis of both fresh and dehydrated material for all stages.

In the field each individual plot comprised two adjacent plants of each clone. These were arranged in the manner of a randomized block experiment with three replications. Since the vegetative stage of growth and the continuous pasture treatments were identical, a total of six replications were available for determining clone differences and effect of sampling at the vegetative stage. All samples were collected during the 1950 season.

TABLE 1.—SUMMARY OF MEAN CAROTENE CONTENT OF FRESH MATERIAL AND PER CENT CRUDE PROTEIN FOR TEN CLONES OF ORCHARDGRASS IN FOUR POLYCROSS NURSERIES SAMPLED AT FOUR STAGES OF GROWTH

Nursery and clone	Vegetative, first cut		Inception of heading		Inception of anthesis		Seed ripe		Mean stages		L.S.D. clones, all stages				Yield score dry matter
											Carotene		Protein		
	Carotene*	Protein†	Carotene	Protein	Carotene	Protein	Carotene	Protein	Carotene	Protein	P = 0.05	P = 0.05	P = 0.05	P = 0.01	
	Mgm.	%	Mgm.	%	Mgm.	%	Mgm.	%	Mgm.	%					
1—Early—															
MI-13	33.5	16.6	15.5	13.9	10.2	9.4	1.2	4.9	15.1	11.2	—	—	—	—	100.0
MI-17	38.1	17.0	18.1	13.7	12.3	13.2	1.7	6.1	17.5	12.5	0.9	1.3	0.9	—	88.6
3—Early—															
MII-46	42.1	18.3	20.4	12.6	18.4	10.3	2.3	7.3	20.8	12.1	—	—	—	—	67.3
MII-49	41.0	18.6	21.4	13.7	19.1	11.2	3.3	6.7	20.9	12.5	—	—	—	—	87.7
MII-50	42.6	18.7	19.2	11.6	19.2	8.7	2.3	6.5	20.8	11.1	—	—	0.6	0.8	100.0
5—Late—															
MIV-6	50.6	21.0	20.7	14.5	16.8	11.4	2.8	7.4	22.7	13.6	—	—	—	—	81.5
MIV-14	56.3	20.5	22.3	13.7	20.0	12.9	4.8	6.0	25.8	13.3	0.7	1.0	—	—	100.0
7—Late—															
XLII-4	37.0	22.0	20.7	12.0	19.3	10.5	1.8	5.6	19.7	11.8	—	—	—	—	89.3
XLI-17	40.7	20.5	21.6	11.1	20.6	9.3	2.2	4.5	21.3	11.7	—	—	—	—	100.0
XLI-23	38.9	19.6	21.5	12.0	19.9	10.3	1.9	5.8	20.5	11.9	0.8	1.1	—	—	91.3
Mean—Stages—											L.S.D. stages				—
Nursery 1	35.8	16.8	16.8	13.8	11.3	11.3	1.5	5.5	—	—	1.3	1.8	1.3	1.9	—
Nursery 3	41.9	18.5	20.3	11.5	18.9	10.1	2.6	6.6	—	—	1.6	2.1	0.7	0.9	—
Nursery 5	53.5	20.8	21.5	14.1	18.4	12.1	3.8	6.7	—	—	1.0	1.4	0.7	1.0	—
Nursery 7	36.9	20.2	21.2	11.7	19.9	10.0	2.0	5.3	—	—	0.9	1.3	0.5	0.7	—

* Carotene is expressed as mgm. per 100 gm. dry matter. F (Clones × Stages) Carotene significant P = 0.05 or less, Nurseries 1 and 5.
† Crude protein is expressed in per cent of dry weight. Protein significant P = 0.05 or less, all nurseries.

Harvesting and Preparation of Samples

Yield samples consisted of the entire top growth of the two-clone plots for all stages, clipped at a height of two inches above the soil. Immediately after harvest a composite sample of 100 gm. (slightly less in later vegetative cuts) free of diseased and discoloured tissue was drawn from each plot and dried in a forced air dryer at 65°-70° C. for 36 hours. Following drying the samples were weighed for determination of dry matter and then ground and placed in manilla bags until required for analysis.

For carotene duplicate samples of 5 gm. from each individual plot were wrapped in cheesecloth and blanched in boiling water for approximately 3 minutes. Immediately after blanching, part of the excess water in the wrapped sample was squeezed out by light pressure and the material was quick frozen between sheets of dry ice. The quick frozen samples were then placed in tightly stoppered vials and stored in a freezing chamber at $-8.5°$ to $-10.0°$ C. until analysed.

Analytical Procedure

Extraction of carotene from the quick frozen (fresh) material was according to the Blendor extraction method of Zscheile and Whitmore (16). Carotene determinations on the extracts were made according to the tentative A.O.A.C. method (1) modified by the use of celite-magnesium oxide 3 : 1 as the chromatographic absorbent.

Crude protein (N $\times$ 6.25) was determined on 1.0 gm. samples of dehydrated material from each replicate according to the Kjeldahl-Gunning-Arnold method as modified by the A.O.A.C. (1).

RESULTS

Effect of Stage of Growth on Carotene and Crude Protein

The mean values for carotene and crude protein for 10 clones of orchardgrass sampled at four stages of growth are summarized in Table 1. Comparative dry matter yield is listed on a score basis, the highest yielding clone being given a score of 100 in each instance. In view of the wide divergence in location of polycross nurseries, differences for stages of sampling and for individual clones throughout the study must be evaluated separately for each nursery. However, in all nurseries significance between stages of growth for both carotene and protein has been demonstrated. A very sharp drop in carotene content has occurred between the vegetative stage and inception of heading with a much slighter drop between heading and anthesis. Although of small degree the decrease in carotene from heading to anthesis was significant for all but Nursery 3. The data for protein content indicate a trend which is in close agreement with that for carotene. As might be expected, both constituents exhibit low values at the seed-ripe stage. The interaction, clones and stages, is significant in all nurseries for protein and in Nurseries 1 and 5 for carotene.

In order to check further on the apparent interrelationships between the constituents examined, correlation coefficients were calculated by stages for the 10 clones. These correlations are listed in Table 2. A significant positive correlation between carotene and protein is evident at the vegetative stage, whereas the relationship is negative and non-significant at heading and anthesis. Dry matter and carotene content have given a significant

TABLE 2.—CORRELATION COEFFICIENTS (r) BY STAGES AND BETWEEN STAGES OF GROWTH FOR TEN CLONES OF ORCHARDGRASS

Comparison	DF	Vegetative	Heading	Anthesis	Seed ripe
Yield of dry matter and carotene content (mgm.) in fresh material	28	+ 0.5788**	+ 0.5785**	+ 0.1543	+ 0.5093**
Yield of dry matter and per cent protein	28	+ 0.4467*	− 0.4893**	+ 0.1251	− 0.4349**
Carotene content (fresh material) and protein content	28	+ 0.5875**	− 0.2131	− 0.1359	+ 0.2163

Comparison	DF	Carotene	Crude protein
Vegetative stage and inception of heading	28	+ 0.5329**	− 0.2449
Vegetative stage and inception of anthesis	28	+ 0.4143*	− 0.0254
Inception of heading and inception of anthesis	28	+ 0.8275**	+ 0.4733**

* Significant, P = 0.05 or less.
** Significant, P = 0.01 or less.

TABLE 3.—SUMMARY OF MEAN CAROTENE CONTENT OF FRESH MATERIAL AND PER CENT CRUDE PROTEIN FOR TEN CLONES OF ORCHARDGRASS IN FOUR POLYCROSS NURSERIES SAMPLED AT THE VEGETATIVE STAGE

Nursery and clone	Cut No. 1		Cut No. 2		Cut No. 3		Cut No. 4		Mean—Cuts		L.S.D. clones, all cuts			
	Carotene*	Protein†	Carotene	Protein	Carotene	Protein	Carotene	Protein	Carotene	Protein	Carotene		Protein	
											P = 0.05	P = 0.01	P = 0.05	P = 0.01
	Mgm.	%	Mgm.	%	Mgm.	%	Mgm.	%	Mgm.	%				
1—Early—														
MI-13	33.5	16.7	—	—	22.9	22.8	16.8	15.3	24.4	16.0	—	—	—	—
MI-17	38.1	17.0	—	—	22.4	23.2	18.5	16.3	26.3	16.6	1.7	—	—	—
3—Early—														
MII-46	41.8	18.4	—	—	27.1	19.0	20.7	17.8	29.9	18.4	—	—	—	—
MII-49	41.1	18.5	—	—	28.4	18.3	20.5	16.5	30.0	17.8	—	—	—	—
MII-50	42.3	18.7	—	—	27.7	18.8	21.9	16.9	30.7	18.1	—	—	—	—
5—Late—														
MIV-6	50.4	20.8	37.2	20.6	32.9	26.1	22.4	19.6	35.7	21.8	—	—	—	—
MIV-14	55.[illegible]	20.8	39.6	22.4	34.4	26.2	25.1	21.3	38.8	22.7	1.8	2.4	0.1	0.2
7—Late—														
XLII-4	38.5	22.0	34.8	18.2	26.4	19.7	22.1	18.7	28.3	19.6	—	—	—	—
XLI-17	41.1	20.6	35.9	18.4	23.4	21.8	21.5	17.4	30.0	19.6	—	—	—	—
XLI-23	39.5	20.2	34.5	18.3	25.0	19.6	21.6	18.6	28.7	19.2	0.5	0.7	—	—
											L.S.D.—Cuts			
Mean—Cuts—														
Nursery 1	35.8	16.8	—	—	22.6	23.0	17.6	15.9	—	—	2.1	3.1	0.2	0.3
Nursery 3	41.7	18.5	—	—	27.7	18.7	21.0	17.1	—	—	1.0	1.3	0.2	0.2
Nursery 5	53.1	20.8	38.4	21.5	33.6	26.1	23.8	20.4	—	—	1.2	1.7	0.2	0.3
Nursery 7	39.0	20.9	35.1	18.3	26.2	20.4	21.7	18.3	—	—	0.4	0.5	0.7	0.9

* Carotene is expressed as mgm. per 100 gm. dry matter. F (Clones × Cuts) Carotene significant P = 0.01 or less, Nurseries 5 and 7.
† Protein is expressed as per cent of dry weight. Protein significant P = 0.05 or less, Nurseries 5 and 7.

positive correlation for the vegetative, heading and seed ripe stages while at anthesis, although the correlation is positive, significance is lacking. The relationship of protein with dry matter yield agrees with that for carotene at only the vegetative and anthesis stages. The correlations between the vegetative, heading and anthesis stages, respectively, indicate a closer relationship between stages for carotene than for protein.

Effect of Frequency of Sampling on Carotene and Crude Protein

Table 3 provides a summary of the mean values for carotene and crude protein obtained from successive samplings at the actively growing vegetative stage. In this table, data for the second cut in Nurseries 1 and 3 have been omitted since weather conditions prevented sampling at the required stage. These particular plots were approaching the heading stage when the second cut was taken. Considering first the L.S.D. values for individual clones, it will be noted that significant differences in carotene content have been obtained for all but Nursery 3. In the case of protein, significant differences for clones have been shown only in Nursery 5. In order to provide a further test of clone differences, carotene and protein values for Nurseries 3, 5 and 7 were corrected for dry matter yield by covariance. In the case of carotene, the clone differences in Nurseries 5 and 7 were confirmed, whereas Nursery 3 again failed to show valid differences. When protein content was adjusted by covariance for yield, significance for clones was increased, with differences being obtained in Nurseries 3 and 7. The level of significance previously shown for protein content of clones in Nursery 5 was reduced slightly by covariance, however.

Upon referring back to Table 3 it will be noted that highly significant differences exist between cuts for both carotene and protein. Carotene has evidenced a rather uniform reduction with successive cuttings. Protein on the other hand has tended to fluctuate in a more irregular fashion.

Evidence was also obtained to indicate that the carotene and crude protein of midsummer samplings were influenced to some degree by early season management. The extent of this effect is shown in Table 4, which provides a comparison of the after-effects of two types of early season management on the clones in three of the nurseries. In the one instance the early season growth was removed at the hay stage (inception of anthesis) followed by sampling of the aftermath at the vegetative stage. Under the other management the plots were sampled at the vegetative (pasture) stage throughout the season. The July and August carotene values tend to be higher in samples taken from plots in which the early season growth was allowed to reach the hay stage than from plots subjected to continuous harvest at the vegetative state. The increase in favour of the early season hay management was significant for the clones in Nurseries 3 and 7. A very similar trend was evident for crude protein with significance also being obtained for managements in Nurseries 3 and 7. In the case of protein all clones tended to behave the same under the two managements as indicated by the lack of significance for the interaction, clones $\times$ managements.

An expression of the total covariance for carotene and crude protein under repeated samplings at the vegetative stage is provided in Table 5. In order to obtain the maximum number of degrees of freedom, the data

TABLE 4.—EFFECT OF EARLY SEASON MANAGEMENT ON CAROTENE CONTENT AND PER CENT CRUDE PROTEIN OF MIDSUMMER CUTS AT THE VEGETATIVE STAGE, FOR EIGHT CLONES OF ORCHARDGRASS IN THREE POLYCROSS NURSERIES

Nursery and clone	Management 1—Hay (June) followed by sampling at vegetative (pasture) stage in July and August						Management 2—Continuous pasture, May to August, inclusive						L.S.D.—Clones, Average 2 Managements			
	Carotene, mgm./100 gm. dry matter			Per cent crude protein			Carotene, mgm./100 gm. dry matter			Per cent crude protein			Carotene		Protein	
	July	August	Av.	July	August	Av.	July	August	Av.	July	August	Av.	P = 0.05	P = 0.01	P = 0.05	P = 0.01
3—Early—																
MII-46	29.6	24.0	26.8	19.4	17.9	18.7	26.8	20.6	23.7	18.9	17.0	17.9	—	—	—	—
MII-49	31.5	27.0	29.3	18.3	18.2	18.3	28.1	20.7	24.4	18.0	16.7	17.4	—	—	—	—
MII-50	32.6	25.5	29.1	19.3	17.6	18.5	29.2	21.7	25.5	19.3	17.1	18.2	0.6	0.8	—	—
5—Late—																
MIV- 6	33.6	23.9	28.7	23.3	22.4	22.8	33.0	22.1	27.5	26.3	19.9	23.2	—	—	—	—
MIV-14	35.5	25.1	30.1	23.9	23.8	23.8	34.3	25.1	29.7	26.9	23.8	24.0	1.2	1.6	0.9	—
7—Late—																
XLII-4	28.7	24.9	26.8	23.1	18.7	20.9	26.6	21.9	24.2	19.6	18.9	19.6	—	—	—	—
XLI-17	34.1	26.1	30.1	24.1	19.0	21.6	27.0	21.4	24.2	22.6	17.4	19.5	—	—	—	—
XLI-23	30.6	25.3	28.0	20.0	20.8	20.4	25.6	21.7	23.1	19.5	17.6	19.3	0.9	—	—	—
Average—													L.S.D.—Managements			
Managements																
Nursery 3			28.4			18.5			24.3			17.8	0.5	0.7	0.6	—
Nursery 5			29.4			23.3			28.6			23.6	—	—	—	—
Nursery 7			28.3			20.9			23.8			19.5	0.7	1.0	1.0	1.3

F (Clones × Managements)—Carotene—significant at P = 0.05 for Nursery 3 and at P = 0.01 for Nursery 7.
Protein —not significant.

TABLE 5.—CORRELATION COEFFICIENT FOR CAROTENE CONTENT OF FRESH MATERIAL AND PER CENT CRUDE PROTEIN AT THE VEGETATIVE STAGE FOR EIGHT CLONES OF ORCHARDGRASS SUBDIVIDED INTO TWO GROUPS

Groups and clones	r (Carotene vs. crude protein)			
	Cut 1	Cut 3	Cut 4	3 Cuts
Group I (Nurseries 3 and 5) MII-46, MII-49, MII-50, MIV-6, MIV-14	+ 0.8859**	+ 0.9204**	+ 0.6159**	+ 0.2575*
Group II (Nursery 7) XLII-4, XLI-17, XLI-23	− 0.4268	+ 0.6243	− 0.3411	+ 0.5492**
D.F. Group I	28	28	28	90
D.F. Group II	16	16	16	54

* Significant P = 0.05 or less.
** Significant P = 0.01 or less.

for frequency of sampling and the continuous pasture management series were combined. This necessitated the omission of data for Nursery 1, this plot having insufficient plants to provide for the additional management treatments.

The correlation coefficients for carotene and crude protein in Table 5 were calculated for the eight clones arranged in two separate groups. This was found necessary in order to provide a clearer picture of the relationship between carotene and protein since the clones in polycross Plot 7 behaved differently in different cuts. The clones in Group I show a highly significant positive correlation for carotene and protein in each of the three cuts. Group II, on the other hand, indicate a negative but non-significant relationship in cuts one and four. In the third cutting a significant and positive r value is obtained. The correlation based on the three cuts combined is of a rather low order for the Group I clones. This is explained by the fact that carotene dropped sharply with successive cuts whereas protein fluctuated in a rather irregular fashion between mid-season cuttings. In Group II this tendency was slightly less and a correlation of slightly higher magnitude was obtained when the data for all cuts were combined.

DISCUSSION

The orchardgrass clones selected for this study have shown trends for carotene at successive growth stages that are in agreement with the findings for other grasses (4, 10, 13). The response of protein content to the varying sampling conditions of the study agrees quite closely with the pattern recorded for carotene. On the whole, however, fluctuations in protein content between stages of maturity, cuts and management systems are of slightly less degree than for carotene. This might well be expected since protein in this instance has reference to all forms of nitrogen within the orchardgrass sample. On the other hand carotene, as defined by the analytical procedure, represents only a small part of the pigment system.

The higher values obtained for cuts following hay in two of the three nurseries studied would seem to be indicative of the comparative vigour of the plants under the two types of utilization. In other words continued

defoliation throughout the season at the active vegetative stage tended to weaken the plants more than when they were allowed to reach a relatively advanced stage prior to the removal of the first harvest. However, the clones in one nursery failed to display a significant management effect. Further study would be necessary to establish this point.

The variations in carotene and crude protein accounted for by stage of growth and sampling frequency stress the necessity for rigidly defining the sampling procedure under which unrelated orchardgrass plants are to be compared. Since the vegetative or leafy stage of early growth has the highest content of the two constituents examined, this stage would be most satisfactory for showing differences in selected material. The tendency for a significant interaction to exist between clones and cuts, and to a degree with early season management, points to the need for comparing plants from a specified cut. The correlation values reported in Table 5 show the highest value for carotene and protein in the third cutting. This would indicate the desirability of discarding the first cutting and sampling the recovery growth to provide for greater uniformity of data. Further uniformity of sampling would be ensured by cutting the plants at a specified height. For example, 6-8 inches was used for defining the vegetative stage in this study.

The correlation values for carotene and crude protein at the vegetative stage were indicative of a degree of relationship between the two constituents. There were some discrepancies, however. These were particularly evident in the clones of Nursery 7, in which negative correlations were obtained in two of three cuttings. This would indicate a possible genetic effect and such being the case there would appear to be some doubt that selection for high protein would ensure a concomitant level of carotene.

SUMMARY

1. A survey was made of the variation in carotene and crude protein content for a selected group of orchardgrass plants that could be accounted for by (*a*) stage of sampling, (*b*) cutting management and (*c*) clones.

2. Marked differences were obtained for both carotene and protein at successive stages of growth.

3. In successive cuttings at the active vegetative stage of growth a seasonal decline in carotene was observed. The behaviour of protein in repeated samplings at the same stage was less uniform. However, the protein content of the last clipping was slightly lower than for the first sampling.

4. The data for the two systems of cutting management indicated a tendency for the carotene content of the fresh material and crude protein to be higher in aftermath clippings following hay than in comparable cuts under continuous pasture sampling.

5. The vegetative stage was considered to be the most satisfactory for defining differences in carotene and crude protein. The interaction of clones $\times$ cuts and clones $\times$ managements further stressed the need for accurately defining sampling period when making comparisons between plant selections.

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WHEAT STREAK MOSAIC IN ALBERTA AND FACTORS RELATED TO ITS SPREAD[1]

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ABSTRACT

Wheat streak mosaic was found on winter and spring wheat in areas of southern Alberta where winter wheat has been grown regularly. Mosaic symptoms were found on only a small percentage of plants in most fields, but in several fields of winter and spring wheat high percentages of plants were infected and crop damage was severe. The damage was most severe in early seeded winter wheat and late seeded spring wheat when the crops were near a source of infection. Preliminary experiments with a mite of the genus *Aceria* found on diseased wheat have indicated a close association between its feeding and the transmission of wheat streak mosaic.

Wheat streak mosaic was found in southern Alberta for the first time in June 1952[2]. This mosaic appears to be identical with a disease first found in Kansas in 1932, which McKinney (2) reported to be caused by a combination of the yellow and mild streak mosaic viruses, *Marmor virgatum* var. *typicum* McK. and *M. virgatum* var. *viride* McK. (3). Since then the disease has damaged wheat crops in several states in the Great Plains region of the United States, especially in Kansas (1). It was studied by the author in South Dakota (4).

The symptoms of streak mosaic include greenish-yellow dashes and streaks parallel to the axes of the leaves. Entire leaves may become chlorotic. The plants usually become stunted, and the yield and grade of grain may be seriously reduced. The disease can be readily transmitted manually by rubbing the juice from diseased plants on the leaves of plants to be infected.

In 1952 streak mosaic was localized in districts of southern Alberta where winter wheat has been grown regularly. In some of these districts the disease occurred in all winter and spring wheat crops examined. Infection ratings were predominantly very low, but in five fields of winter wheat and two of spring wheat, between 70 per cent and 100 per cent of the plants were infected, and these crops suffered severe reductions in yield.

The percentage of infected plants and the severity of the disease in spring and winter wheat appeared to depend on the nearness of the crop to a source of infection, and on the date of seeding. Mosaic was severe in winter wheat crops that were seeded early in August 1951 and were situated near a wheat crop that could have carried the virus through the summer. Severe infections of spring wheat occurred in fields adjacent to winter wheat that had harboured the virus over winter. Damage was more severe in late than in early seeded spring wheat.

Plot experiments in which wheat was seeded at successive dates from early summer until late fall showed that streak mosaic spread rapidly in the field throughout the summer and early fall. Since experimental evidence was consistently negative for transmission through seed or soil, attempts were made to find an insect vector responsible for the natural spread of the

[1] Contribution No. 1254 from the Division of Botany and Plant Pathology, Science Service, Department of Agriculture, Ottawa, Canada.

[2] Samples sent to H. H. McKinney were identified by him as a strain of the wheat streak mosaic virus.

TABLE 1.—THE RELATION OF MITES TO THE DEVELOPMENT OF CHLOROSIS AND STREAK MOSAIC ON WHEAT SEEDLINGS GROWN IN STERILIZED SOIL IN TEST TUBES

Treatment	Number of wheat seedlings*			
	Total tested	No symptoms	Chlorosis only	Chlorosis and streak mosaic
1 or 2 mites per seedling	56	13	27	16
No mites	30	30	0	0

* The presence of streak mosaic in all seedlings was tested by manual inoculation of healthy wheat plants.

mosaic virus. Various types of plant-feeding insects collected in wheat crops severely infected with mosaic were caged on test plants in the greenhouse. Occasionally a small number of test plants became infected in experiments with most of the insects; hence special emphasis was placed on the smaller insects such as thrips that could easily pass through the 32 mesh per inch screen of the cages used for aphids, leafhoppers, and other larger insects. However, experiments with various types of thrips also gave inconclusive results. It was found that cages made of 112 mesh sheer nylon, which proved effective in confining or excluding thrips, did not protect pot-grown wheat plants from becoming infected with the virus when placed in a field where the disease was spreading. A vector even smaller than thrips was suspected.

Examination of naturally infected wheat plants with a hand lens and with a low-power microscope revealed the presence of a tiny mite of the genus *Aceria* in the family Eriophyidae*. Pieces of mosaic-infected leaves bearing the mites were placed adjacent to young wheat plants in pots in the greenhouse. As the pieces of mite-bearing leaves dried, the mites migrated to the living plants. Within a day the margins of the leaves of some of the plants began to curl upward. Eventually some of the leaves became tightly rolled. Chlorotic symptoms resembling those of streak mosaic also developed. By manual inoculation mosaic was transmitted from some of the plants showing chlorotic streak symptoms. In other experiments mites were transferred singly from mosaic-diseased leaves to wheat seedlings protected by thrips-proof cages. The combined results of three experiments, in which one or two mites were transferred to each wheat plant, showed 87 of 199 plants developing mosaic-like symptoms. Similar symptoms developed on three of the 62 check plants to which mites were not intentionally transferred, but in these cases mites were found when the diseased plants were examined with a lens.

In order to secure control over the movements of the mites, wheat seedlings were grown singly in sterilized soil in 2.3 cm. × 30 cm. test tubes tightly plugged with cotton. Mites were transferred singly from wheat with mosaic type symptoms to some of the seedlings in test tubes, and other seedlings were kept mite-free. In about seven days chlorotic spots and streaks began appearing on some of the young plants on which mites were feeding. Careful manual inoculations were made to check the presence of

* The mite was identified by H. H. Keifer, State of California Department of Agriculture, Sacramento, Calif.

mosaic on all the plants. The leaves of individual plants were ground in small mortars. The juices were diluted with approximately 20 parts of water and filtered through Cenco No. 13250 qualitative filter papers. This eliminated any possibility of live mites being present in the filtrates which were used to inoculate wheat plants in the two-leaf stage by the carborundum-rub method. The combined results of three experiments are shown in Table I. Various chlorotic symptoms developed on most of the seedlings on which mites had been placed, and streak mosaic was transmitted from about one-third of them. It therefore appears that the mites can transmit streak mosaic, but they can also induce other chlorotic symptoms that resemble but are not related to streak mosaic.

Experiments are in progress to rear colonies of mites free from the mosaic virus to be used in further experiments on the relation of the mites to streak mosaic.

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GROWTH CRACKS IN WHEAT SEED

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Soon after harvesting of the 1951 crop was begun in Western Canada, specimens of wheat were received that showed longitudinal splitting of the pericarp and testa. The cracks have been observed only on the ventral side of the kernel in a median position on the cheeks. The exposed endosperm is clearly visible in affected seed (Figure 1, *A* and *B*). The opaque appearance of the endosperm in the portion of the kernel adjacent to the fracture is indicative of moisture penetration. This is evident in a transverse section of the kernel (Figure 1, *B*). The exposed endosperm is usually discoloured in kernels that have been stored while in a tough or damp condition.

Growth cracks were observed in plump, well-matured kernels, in poorly matured, shrunken kernels, and in frosted kernels. They were more common in the two latter classes, which are usually associated with late maturity. Most of the specimens received at this laboratory were of the Thatcher variety, but samples from experimental plots revealed growth cracks in seed of Reward, Marquis, Red Bobs, Sevier, and several lines of hybrid material.

Information received from R. A. Ingalls, District Analyst, Plant Products Laboratory, Saskatoon, Sask., indicates that the incidence of growth cracks in Manitoba-grown wheat was very low and that it increased to the west, reaching its peak in southern Alberta. In Saskatchewan, samples were seen with 5 or 6 per cent of affected kernels, but the incidence was usually less than 1 per cent. In general, late maturity and delay in harvesting, due to rain and snow in 1951, increased from Manitoba westward into Alberta.

The cause of the trouble is not known, but it appears to be related in some way to slow maturation of the crop as a result of excessive moisture and cool weather. Although evidence is lacking, it is possible that 2,4-D weed sprays may have contributed to the abnormality. Godbout (1) reports a delay in maturity and certain deformities in oats following 2,4-D treatments. Various formulations of this herbicide are widely used in Western Canada and deformities commonly appear in treated plants. Some delay in maturity of wheat treated with 2,4-D was observed by members of this laboratory during a field-trip in September 1951. In a few instances the cracks were seen in kernels taken from unthreshed heads, and it is the opinion of the author that mechanical injury in threshing was not responsible for much of the trouble.

Thus far, this abnormality is of minor importance because of its comparatively rare occurrence. However, fractures of the main protective layers of the kernel, the pericarp and testa, leave the seed open for infection by soil organisms. Furthermore, in tough or damp stored grain the exposed endosperm provides an excellent locus for colonization of moulds.

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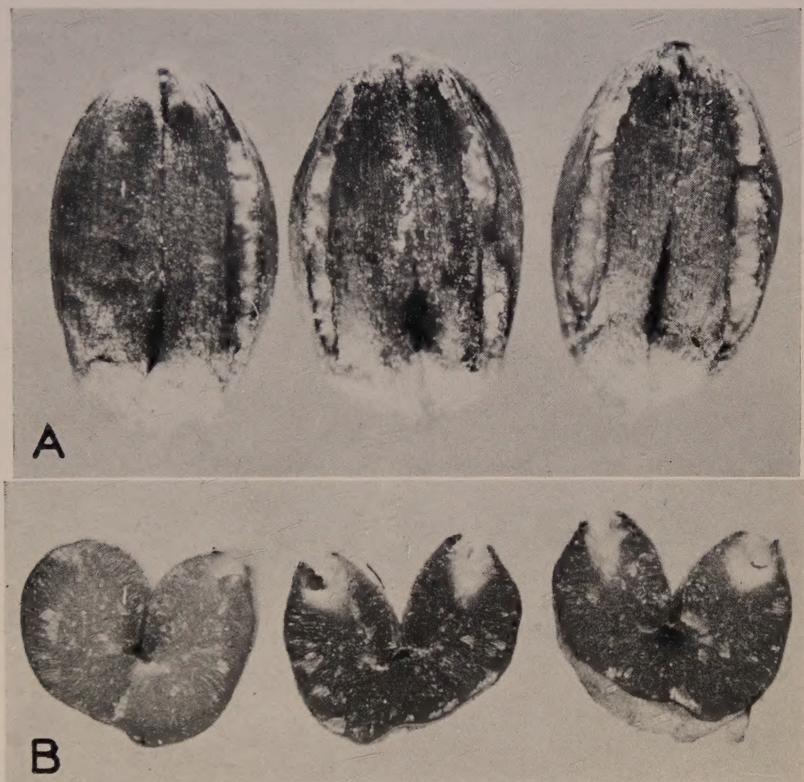

FIGURE 1. Wheat kernels showing cracks. *A*. Ventral view showing ruptured pericarp and testa exposing the endosperm. *B*. Transverse sections showing white endosperm tissue caused by moisture penetration.

Anderson (2) refers to the same type of abnormality as follows: "The term ruptured was selected by the Chief Inspector to name a peculiar longitudinal splitting of the bran on the cheeks of kernels. This type of damage occurred in noticeable amounts in a few areas in southern Alberta. It was generally accompanied by a rather severe infection with saprophytic moulds that flourished on the exposed endosperm."

REFERENCE

1. Godbout, E. Effects of herbicides on cereal crops (oats). Proc. of the 4th Meeting, Eastern Section, National Weed Committee, Ottawa, Canada, pp. 21–23. 1951.
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